63-3-3

SEMICONDUCTOR RELIABILITY

Third Quarterly Report

1 January - 31 March 1963

Contract NObsr-87664
Department of the Navy
Bureau of Ships

30 April 1963

Report prepared by
George J. Blakemore

ARINC Research Corporation
a subsidiary of Aeronautical Radio, Inc.
1700 K Street, N. W.
Washington 6, D. C.

Publication No. 239-01-3-359

FOREWORD

This report presents the results of work performed by ARINC Research Corporation during the quarter 1 January - 31 March 1963 for the Bureau of Ships, Department of the Navy, under Contract NObsr-87664. The contract authorized a research program to determine quality assurance requirements for specific semiconductor devices, and to determine confidence limits for the shape parameter β of the Weibull distribution. Work performed in the first and second quarters of the contractual period, 1 July - 30 September 1962 and 1 October - 31 December 1962, was described in Publications No. 239-1-325 and No. 239-2-338, respectively. The program is similar in scope to research conducted for the Bureau of Ships under a previous contract, NObsr-81304, and reported in ARINC Research Publication No. 144-6-270.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

1. PURPOSE

This study under Contract NObsr-87664 is similar in scope to an earlier study made under Contract NObsr-81304. Final results of that study were reported in ARINC Research Publication No. 144-6-270, Reliability of Semiconductor Devices, 22 December 1961.

The work under the present contract has three basic objectives:

(1) To determine quality assurance requirements for 23 specified semiconductor devices. For this purpose, reliability and life test data, obtained from manufacturers of semiconductor devices and equipment and from field use, will be analyzed and integrated.

(2) To provide specifically from the data:

(a) Information on failure rates from life tests and field operation.

(b) Application data based on the variability of important electrical characteristics under life test conditions.

(c) Information on decreasing failure rates and on responses of different junction types to application of various stresses.

2. GENERAL FACTUAL DATA

ARINC Research personnel who have participated in the study and the man-hours expended by them through 31 March 1963 are as follows:

	Hours
Robert Strauss, Program Manager	21
George J. Blakemore, Program Director-Statistician	1033
Edward T. Kronson, Statistician-Programmer	686
William H. von Alven, Technical Consultant	39

3. DETAILED FACTUAL DATA

3.1 Summary of Work Performed

During the third quarter, manufacturers provided life test data on 3 semiconductor devices. Thus, life test data for the 23 specified transistor types to be studied under this contract have now been received from the 8 manufacturers who agreed to contribute to the study. (Success in acquiring the data is largely due to the efforts and cooperation of representatives of these manufacturers on the JEDEC JS-11 Committee.)

This report presents a detailed analysis of the life test data on 8 transistor types.

3.2 Analysis of Semiconductor Life Test Data

This report presents the results of analysis of data from short-term (1000-hour) life tests of 8 transistor types. Table 1 lists these transistors, the types of life tests, the sample sizes, and the specific electrical parameters considered. As in the first and second quarterly reports*,

* G. J. Blakemore, Reliability of Semiconductor Devices, First Quarterly Report, 31 October 1962, ARINC Research Corporation, Publication No. 239-1-325, pp. 5-20.

G. J. Blakemore, E. T. Kronson, and W. H. Von Alven, Reliability of Semiconductor Devices, Second Quarterly Report, 31 January 1963, ARINC Research Corporation, Publication No. 239-2-338, pp. 19-86.

TABLE 1

TYPES AND CLASSES OF TRANSISTORS ANALYZED;
TYPES OF LIFE TESTS, SAMPLE SIZES, AND ELECTRICAL PARAMETERS

Type	Class	Life Tests	Sample Size	Electrical Parameters
2N1485 } *2N1486 }	NPN-Silicon-Medium Power	1. 200°C Storage 2. Cycled Operating	60 60	h_{FE}, I_{CBO}
2N2084	PNP-Germanium-Switch	1. 100°C Storage 2. 100mW Operating	30 30	h_{FE}, I_{CBO}
2N1204	PNP-Germanium-Switch	1. 100°C Storage 2. 200mW Operating	110 50	V_{CE}, I_{CBO}
2N914 } 2N916 }	NPN-Silicon-Radio Frequency	1. 300°C Storage 2. 300mW Operating	80 200	h_{FE}, I_{CBO}
2N962 } 2N964 }	PNP-Germanium-Switch	1. 100°C Storage 2. 150mW Operating	120 200	h_{FE}, I_{CBO}

Note: The brackets indicate that the life test data for the two types were submitted in a combined form. Therefore, the data for the two types are combined in this report.

* Type 2N1486 was not on the original list of transistor types for which analysis was requested.

the analysis consists of four parts:

(1) Distribution of electrical parameter readings at successive time periods.

(2) Distribution of the change in electrical parameter readings at 1000 hours relative to the initial readings (delta distributions).

(3) Graphical estimation of the Weibull distribution shape parameter β and scale parameter α.

(4) Determination of hazard rates based on the graphically estimated Weibull parameters.

3.2.1 Electrical Parameter Distributions

Figures 1 through 20* illustrate the sample cumulative percentage distributions of electrical parameters for the 8 transistor types listed in Table 1. The cumulative

* All figures and tables appear at the end of Section 3.2.3.

percentages are plotted versus the electrical parameter readings, and a smooth curve is drawn through the resulting points. For reasons explained in the first quarterly report, these distributions are presented on normal-probability graph paper.

The figures indicate the minimum and maximum values for the two failure criteria employed: initial and life test specification limits. Since military specification limits were available for only transistor types 2N1485 and 2N1486 (Figures 1 through 4), the figures for the other 6 transistor types show values for specification limits that appeared on the data submitted by the respective manufacturers.

Figures 1 through 20 also indicate the sample size on which each distribution is based.

3.2.2 Delta Distributions

Figures 21 through 30 show delta distributions on normal-probability graph paper. These distributions - one for each electrical parameter, life test, and device type listed in Table 1 - illustrate the stability of the electrical parameters during the life test period of 1000 hours.

As in the first and second quarterly reports, the relationship used is:

$$\Delta P = \frac{P_t - P_o}{P_o}$$

where

P = the electrical parameter of interest,

P_t = the reading of the parameter at some time period $t > 0$ (here, $t = 1000$ hours), and

P_o = the reading of the parameter at zero hours.

In Figures 21 through 30, all readings of ΔP are in percent. For the 2N1204, 2N1485, and 2N1486 transistor types, some ΔI_{CBO} readings are greater than the highest value shown on their respective ordinate scales; the actual maximum readings are indicated at the top of the graphs.

3.2.3 Weibull Parameter Estimation

Tables 2 through 6 present, for each of the 8 transistor types listed in Table 1, the number of failures observed per sample size at successive reading points of 1000-hour life tests. The number of failures per sample size is given for each electrical parameter and for the parameters combined. Also shown is the total number of failures that occurred during the life tests for each parameter and the combined parameters. All failures are shown in terms of the life test conditions (see Table 1) and in terms of the two failure criteria - initial and life test specification limits.

The sample size and number of failures shown for each time interval are applicable to that interval only; i.e., the sample size listed is the number of units which, at the start of the interval, had not failed during any previous interval, and the number of failures listed is the number which failed during that interval alone. Occasionally, the sample size for a particular time interval is less than would be expected, given the number of failures that occurred in the preceding time interval. This discrepancy results from removal of units from the life test without the occurrence of failures.

In addition, Tables 2 through 6 list graphical estimates of the Weibull shape parameter β and scale parameter α, where applicable. These estimates are based on the failure data accompanying each set of estimates in the table. The estimates of the parameter α are in the kilo-scale. To convert these without reference to scale, one multiplies the α estimates by $10^{3\beta}$, where β is the corresponding β estimate given in the adjoining column. Dashes in the β and α columns indicate that estimates of the parameters could not be made by this graphic estimation technique because of insufficient failures.

An examination of Tables 2 through 6 immediately shows that the number of failures for each transistor type is so

negligible that no estimates of practical statistical significance could be obtained.

This lack of significant estimates of the Weibull parameters β and α was true not only for the 8 transistor types analyzed in this report, but for most of the devices analyzed in the previous quarterly reports under this contract.

Investigation of this problem will continue during the last quarter and will be discussed in detail in the final report, to be issued 31 July 1963.

TABLE 2

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): FAILURES PER SAMPLE SIZE FOR TWO ELECTRICAL PARAMETERS BASED ON INITIAL AND LIFE TEST SPECIFICATION LIMITS FOR THREE TIME INTERVALS OF TWO 1000-HOUR LIFE TESTS; GRAPHICAL ESTIMATES OF WEIBULL PARAMETERS β AND α

	Storage Life at 200°C (n = 60)						Cycled Operating Life (n = 60)					
					Weibull Parameters						Weibull Parameters	
Electrical Parameter	250 Hours	500 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)	250 Hours	500 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)
INITIAL LIMITS												
h_{FE}	0/60	0/60	0/60	0	0	-	0/60	0/60	0/60	0	0	-
I_{CBO}	0/60	0/60	0/60	0	0	-	1/60	0/59	0/59	1	0	60.5
Combined	0/60	0/60	0/60	0	0	-	1/60	0/59	0/59	1	0	60.5
LIFE TEST LIMITS												
h_{FE}	0/60	0/60	0/60	0	0	-	0/60	0/60	0/60	0	0	-
I_{CBO}	0/60	0/60	0/60	0	0	-	0/60	0/60	0/50	0	0	-
Combined	0/60	0/60	0/60	0	0	-	0/60	0/60	0/60	0	0	-

TABLE 3

TRANSISTOR TYPE 2N2084, SOURCE H: FAILURES PER SAMPLE SIZE FOR TWO ELECTRICAL PARAMETERS BASED ON INITIAL AND LIFE TEST SPECIFICATION LIMITS FOR ONE TIME INTERVAL OF TWO 1000-HOUR LIFE TESTS;
GRAPHICAL ESTIMATES OF WEIBULL PARAMETERS β AND α

	Storage Life at 100°C (n = 30)				Operating Life at 100mW (n = 30)			
Electrical Parameter	1000 Hours	Total Failures	Weibull Parameters		1000 Hours	Total Failures	Weibull Parameters	
			β	α (Kilo Scale)			β	α (Kilo Scale)
INITIAL LIMITS								
h_{FE}	0/30	0	0	-	0/30	0	0	-
I_{CBO}	0/30	0	0	-	0/30	0	0	-
Combined	0/30	0	0	-	0/30	0	0	-
LIFE TEST LIMITS								
h_{FE}	0/30	0	0	-	0/30	0	0	-
I_{CBO}	0/30	0	0	-	0/30	0	0	-
Combined	0/30	0	0	-	0/30	0	0	-

TABLE 4

TRANSISTOR TYPE 2N1204, SOURCE I: FAILURES PER SAMPLE SIZE FOR TWO ELECTRICAL PARAMETERS BASED ON INITIAL AND LIFE TEST SPECIFICATION LIMITS FOR THREE TIME INTERVALS OF TWO 1000-HOUR LIFE TESTS; GRAPHICAL ESTIMATES OF WEIBULL PARAMETERS β AND α

	Storage Life at 100°C (n = 110)						Operating Life at 200mW (n = 50)					
					Weibull Parameters						Weibull Parameters	
Electrical Parameter	316 Hours	646 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)	250 Hours	500 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)
INITIAL LIMITS												
V_{CE}	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-
I_{CBO}	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-
Combined	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-
LIFE TEST LIMITS												
V_{CE}	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-
I_{CBO}	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-
Combined	0/110	0/110	0/110	0	0	-	0/50	0/50	0/50	0	0	-

TABLE 5

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): FAILURES PER SAMPLE SIZE FOR TWO ELECTRICAL PARAMETERS BASED ON INITIAL AND LIFE TEST SPECIFICATION LIMITS FOR THREE TIME INTERVALS OF TWO 1000-HOUR LIFE TESTS; GRAPHICAL ESTIMATES OF WEIBULL PARAMETERS β AND α

Electrical Parameter	Storage Life at 300°C (n = 80)						Operating Life at 300mW (n = 200)					
	125 Hours	500 Hours	1000 Hours	Total Failures	Weibull Parameters		125 Hours	500 Hours	1000 Hours	Total Failures	Weibull Parameters	
					β	α (Kilo Scale)					β	α (Kilo Scale)
INITIAL LIMITS												
h_{FE}	0/80	0/80	0/80	0	0	-	0/200	0/200	0/200	0	0	-
I_{CBO}	1/80	0/79	0/79	1	0	81.0	0/200	0/200	0/200	0	0	-
Combined	1/80	0/79	0/79	1	0	81.0	0/200	0/200	0/200	0	0	-
LIFE TEST LIMITS												
h_{FE}	0/80	0/80	0/80	0	0	-	0/200	0/200	0/200	0	0	-
I_{CBO}	1/80	0/79	0/79	1	0	81.0	0/200	0/200	0/200	0	0	-
Combined	1/80	0/79	0/79	1	0	81.0	0/200	0/200	0/200	0	0	-

TABLE 6

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): FAILURES PER SAMPLE SIZE FOR TWO ELECTRICAL PARAMETERS BASED ON INITIAL AND LIFE TEST SPECIFICATION LIMITS FOR THREE TIME INTERVALS OF TWO 1000-HOUR LIFE TESTS; GRAPHICAL ESTIMATES OF WEIBULL PARAMETERS β AND α

	Storage Life at 100°C (n = 120)						Operating Life at 150mW (n = 200)					
					Weibull Parameters						Weibull Parameters	
Electrical Parameter	125 Hours	500 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)	125 Hours	500 Hours	1000 Hours	Total Failures	β	α (Kilo Scale)
INITIAL LIMITS												
h_{FE}	1/120	0/119	0/119	1	0	122.0	0/200	0/200	1/200	1	-	-
I_{CBO}	0/120	0/120	0/120	0	0	-	0/200	2/200	1/198	3	0.55 (500-1000 Hours)	66.7 (500-1000 Hours)
Combined	1/120	0/119	0/119	1	0	122.0	0/200	2/200	2/198	4	1.00 (500-1000 Hours)	50.4 (500-1000 Hours)
LIFE TEST LIMITS												
h_{FE}	0/120	0/120	0/120	0	0	-	0/200	0/200	0/200	0	0	-
I_{CBO}	0/120	0/120	0/120	0	0	-	0/200	2/200	1/198	3	0.55 (500-1000 Hours)	66.7 (500-1000 Hours)
Combined	0/120	0/120	0/120	0	0	-	0/200	2/200	1/198	3	0.55 (500-1000 Hours)	66.7 (500-1000 Hours)

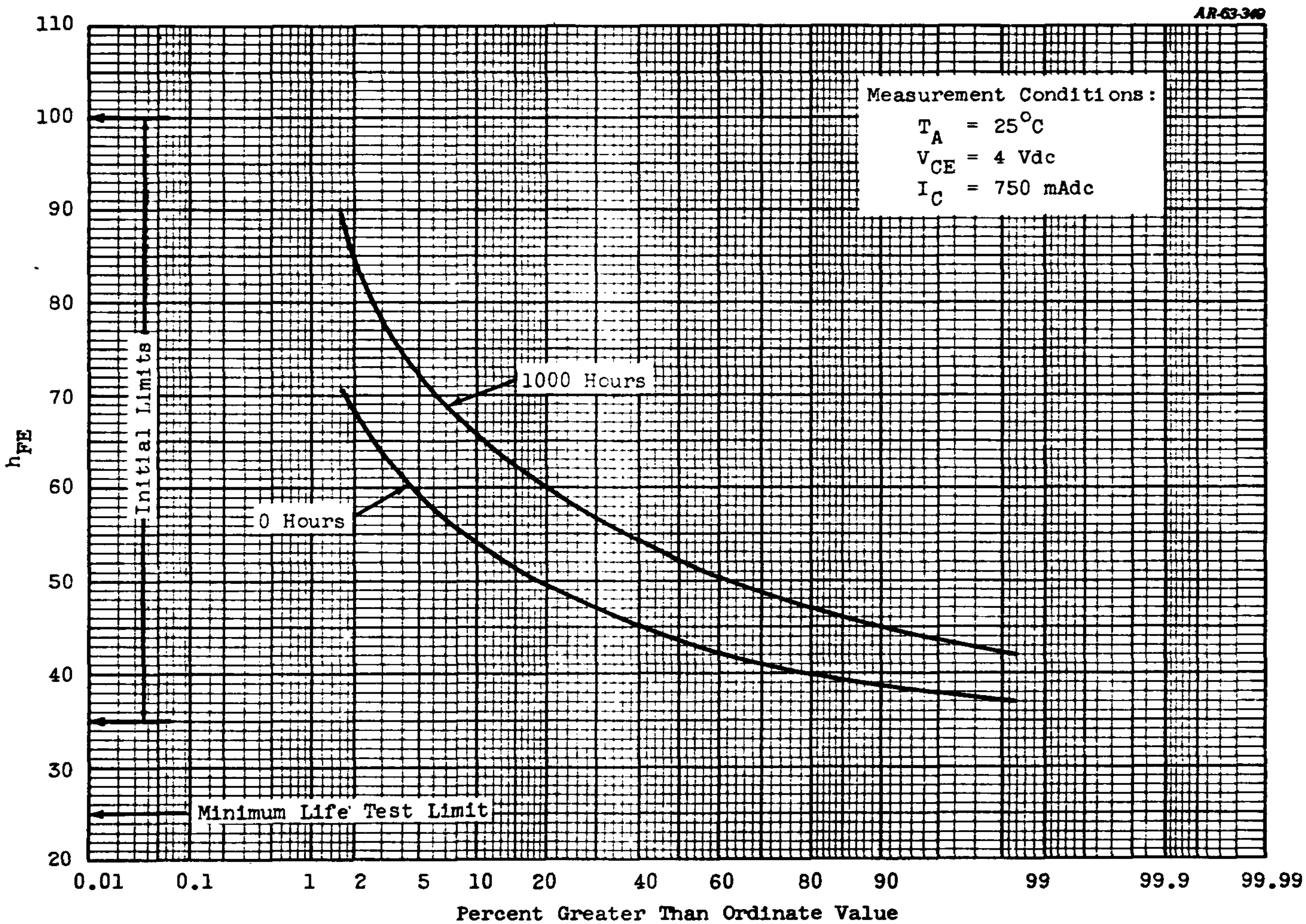

FIGURE 1

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 200°C STORAGE LIFE TEST (n = 60)

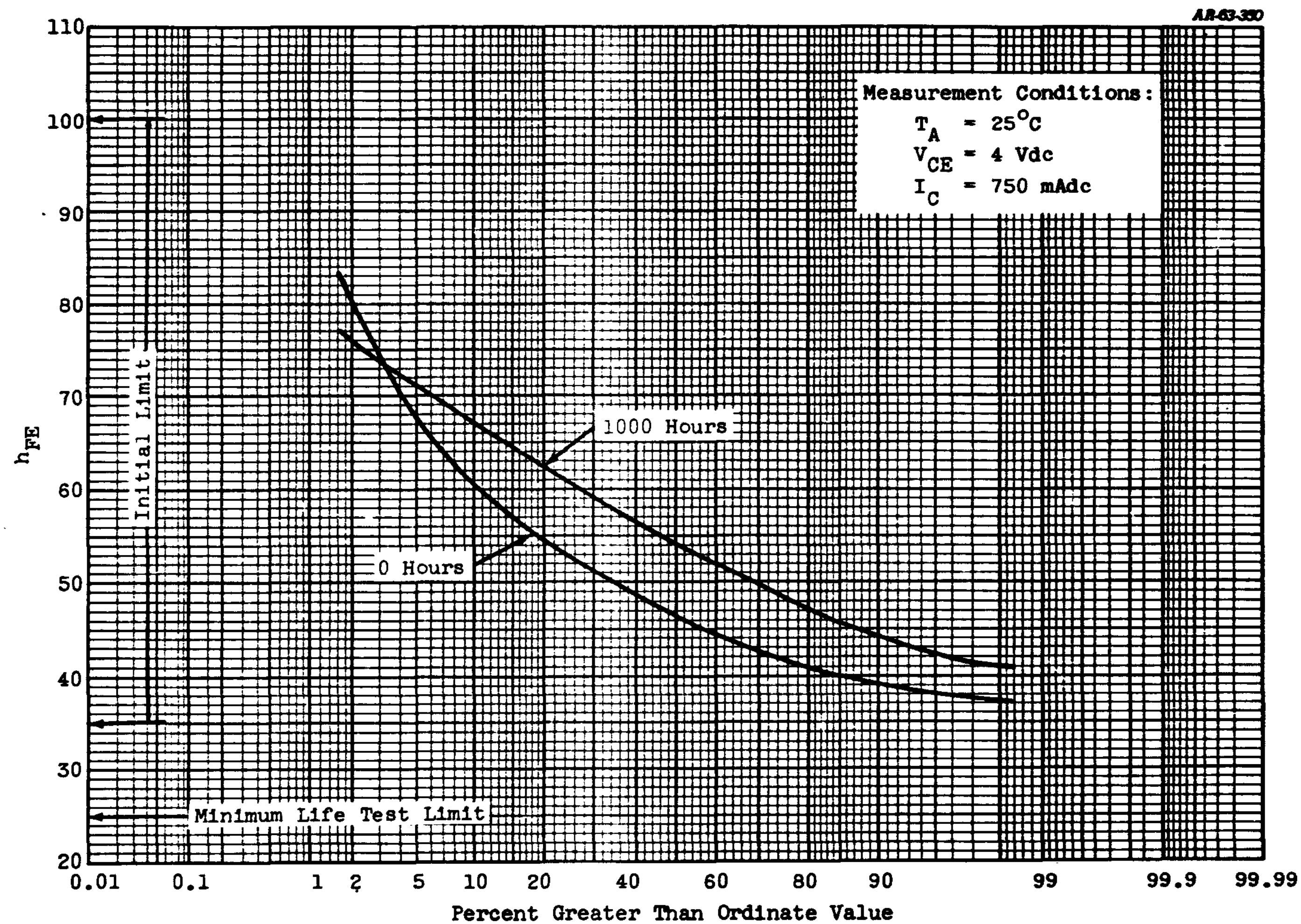

FIGURE 2

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, CYCLED OPERATING LIFE TEST (n = 60)

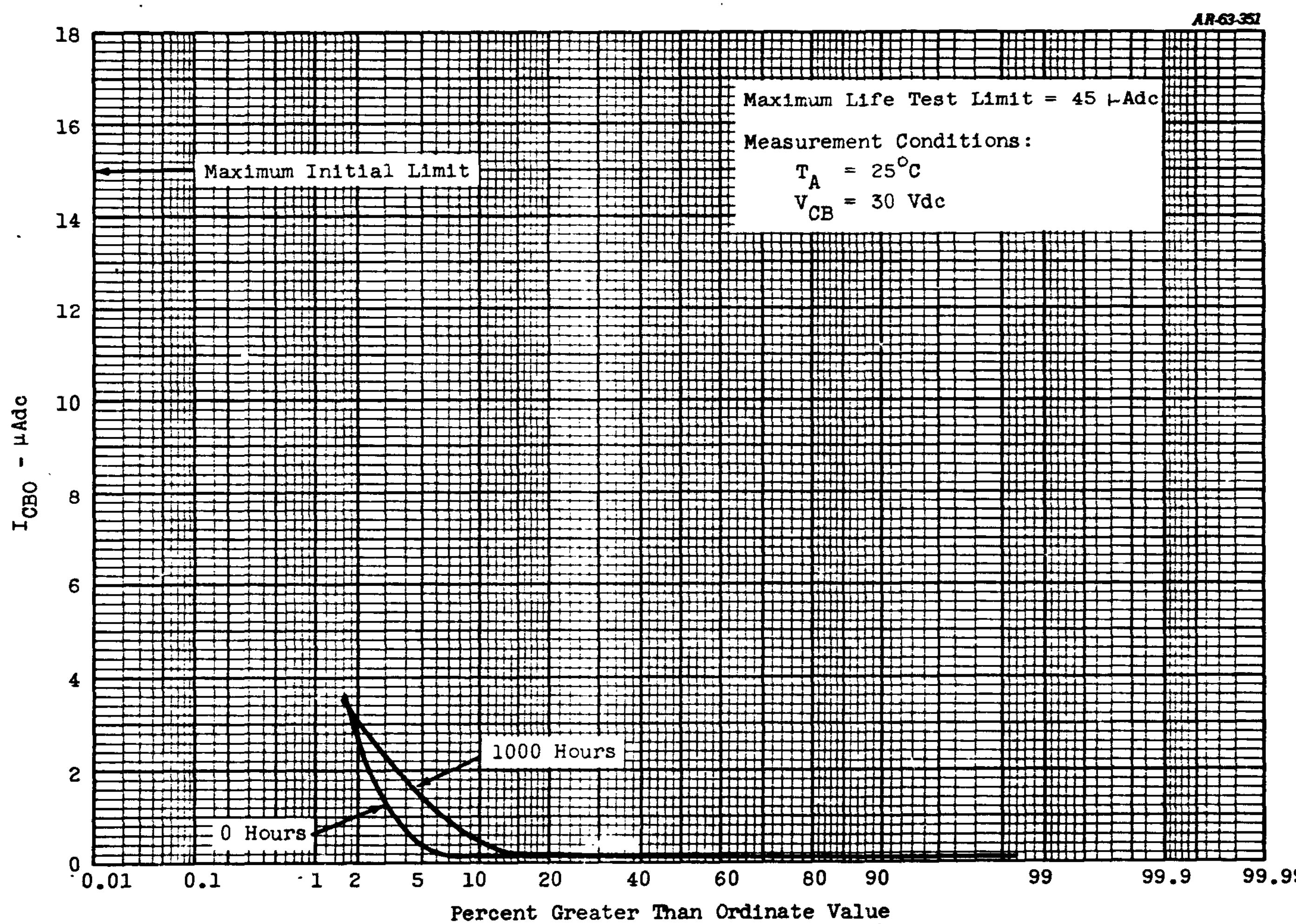

FIGURE 3

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 200°C STORAGE LIFE TEST (n = 60)

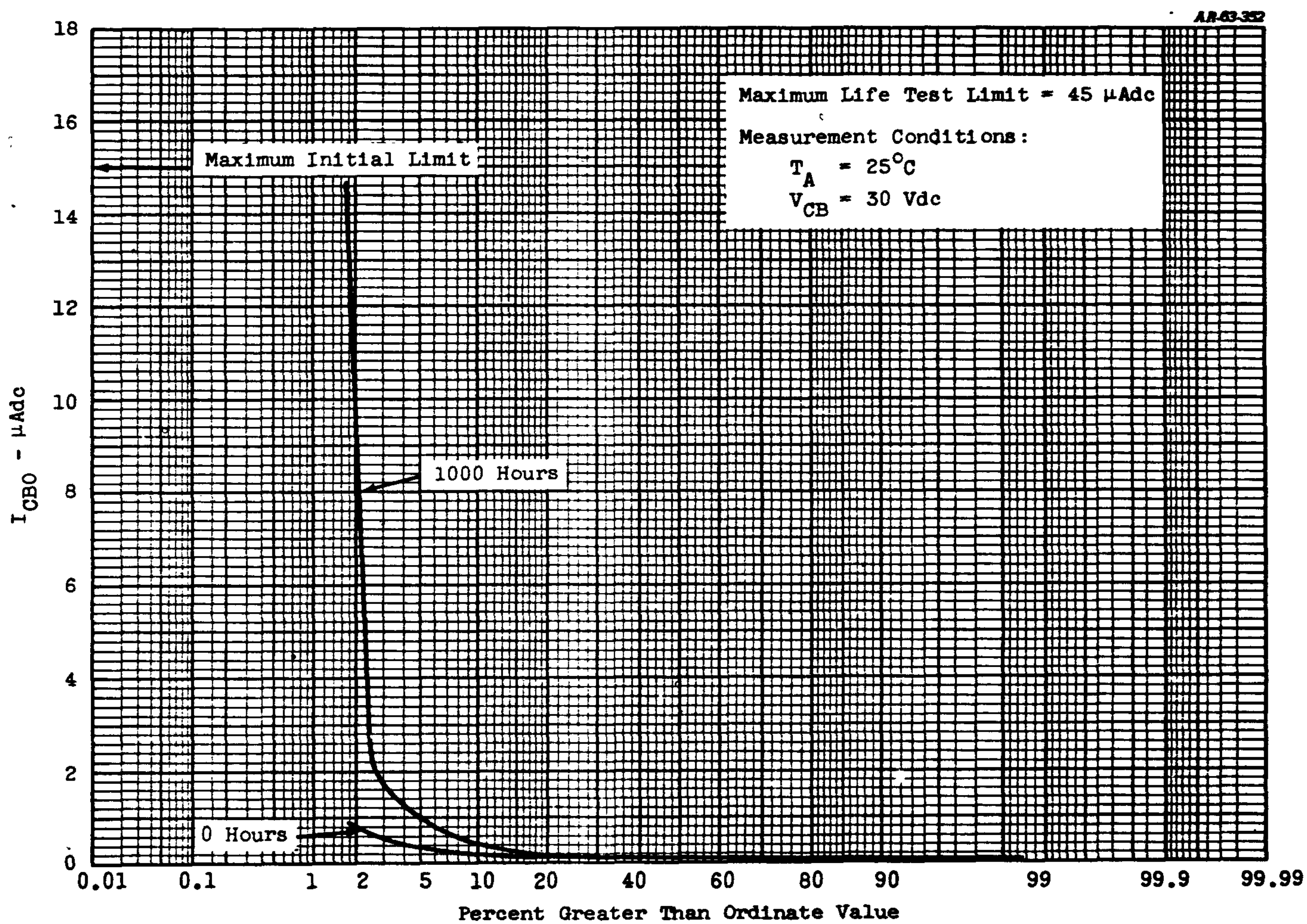

FIGURE 4

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, CYCLED OPERATING LIFE TEST (n = 60)

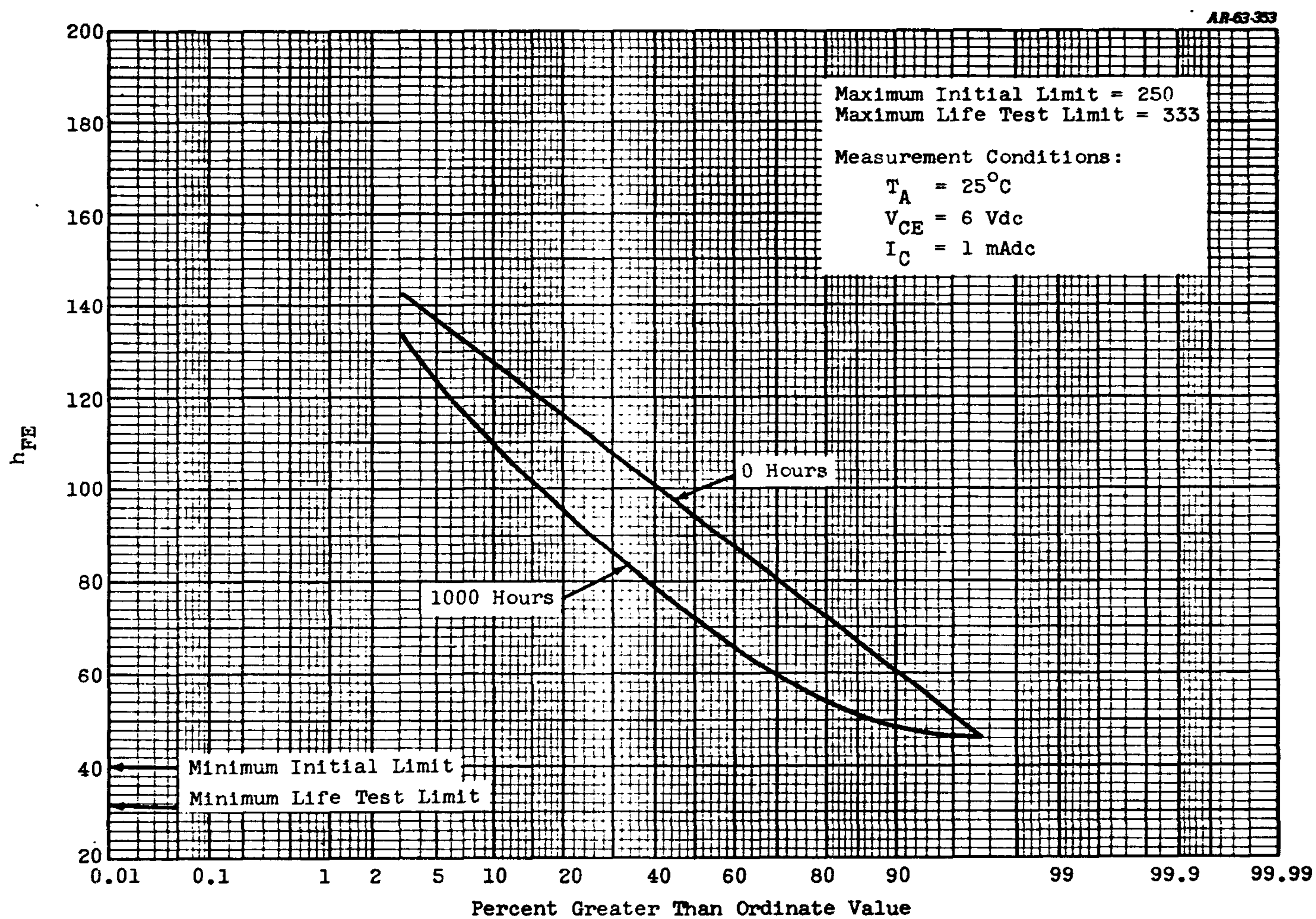

FIGURE 5

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 30)

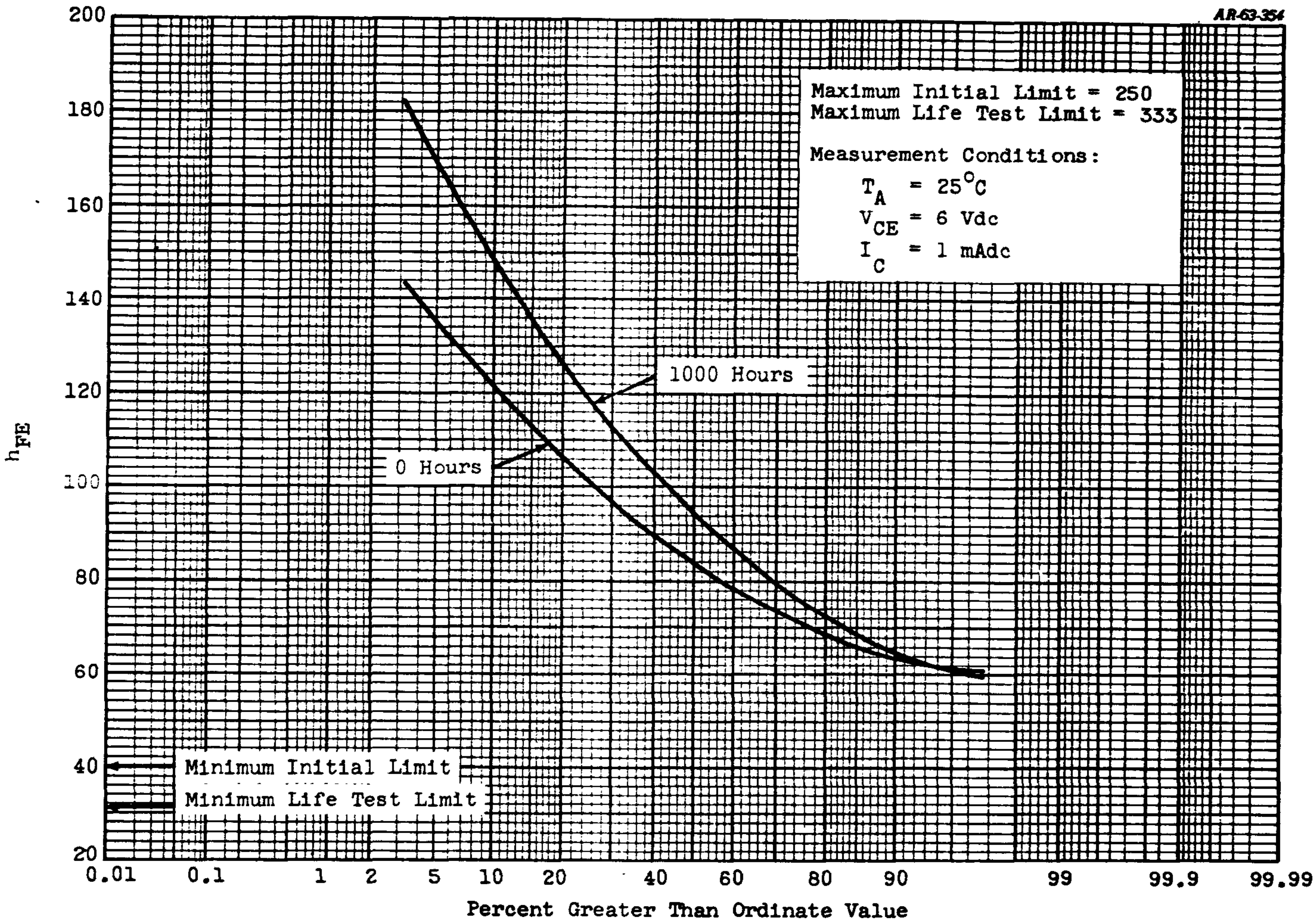

FIGURE 6

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 100mW OPERATING LIFE TEST (n = 30)

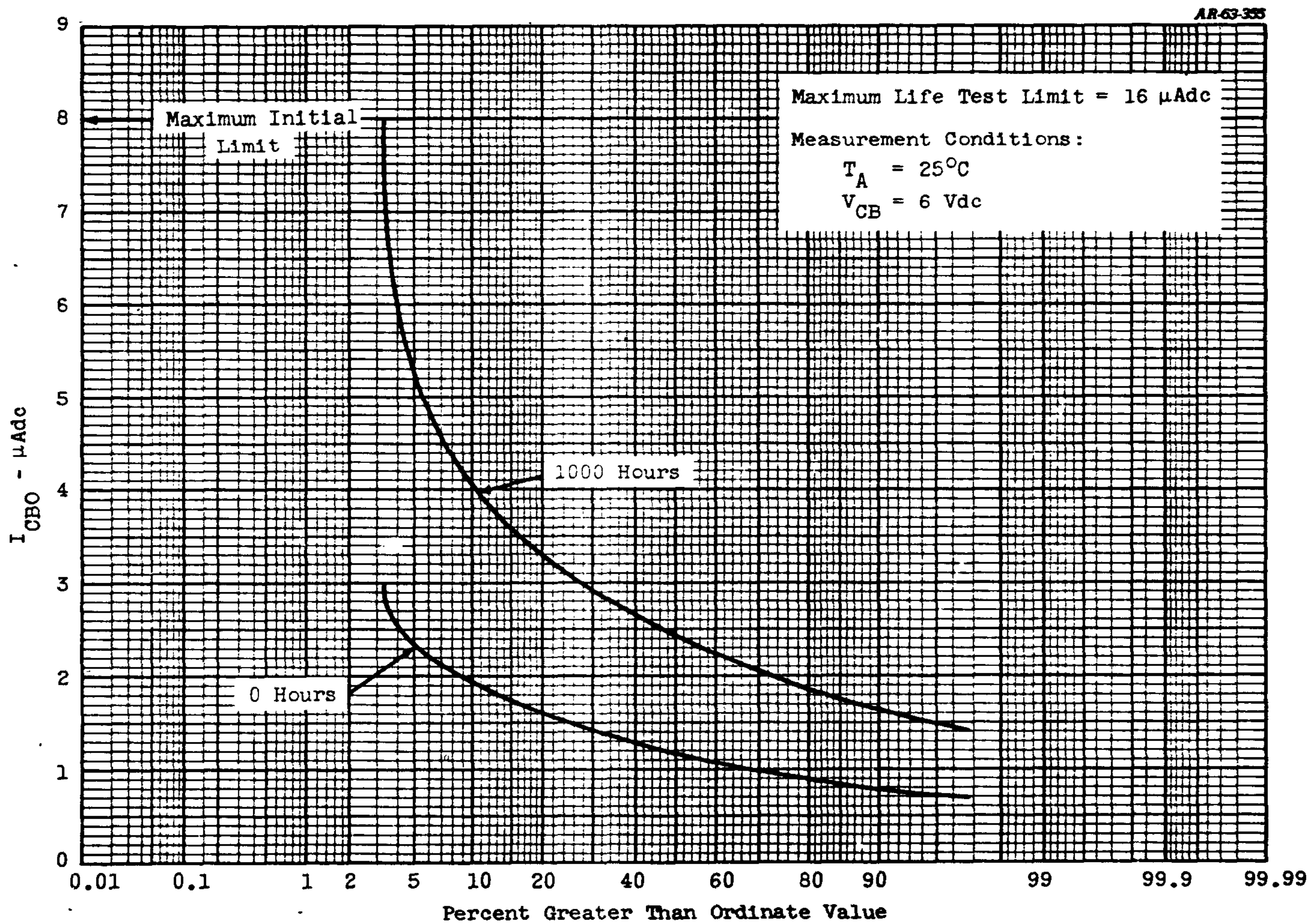

FIGURE 7

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 30)

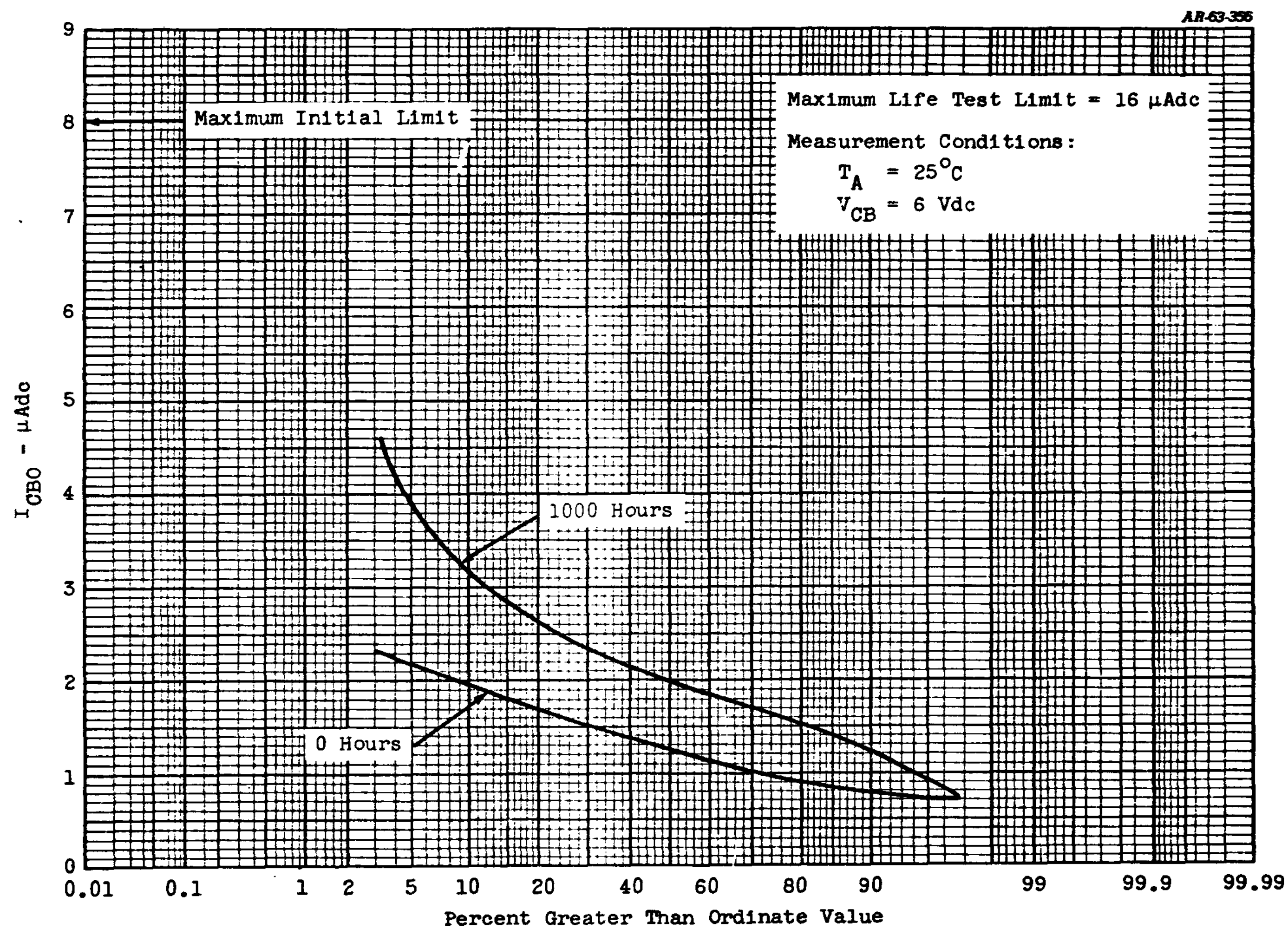

FIGURE 8

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 100mW OPERATING LIFE TEST (n = 30)

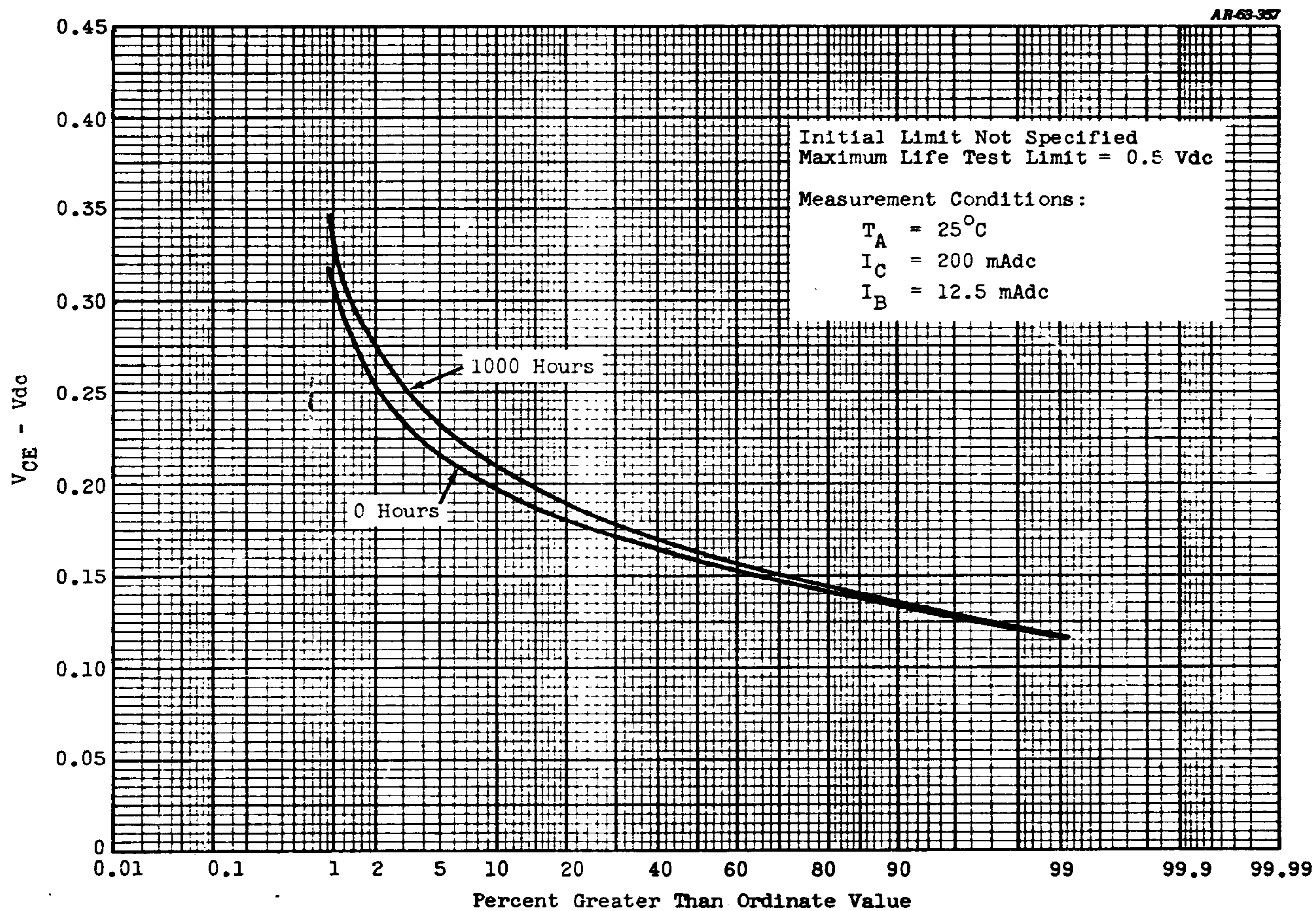

FIGURE 9

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF V_{CE} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 110)

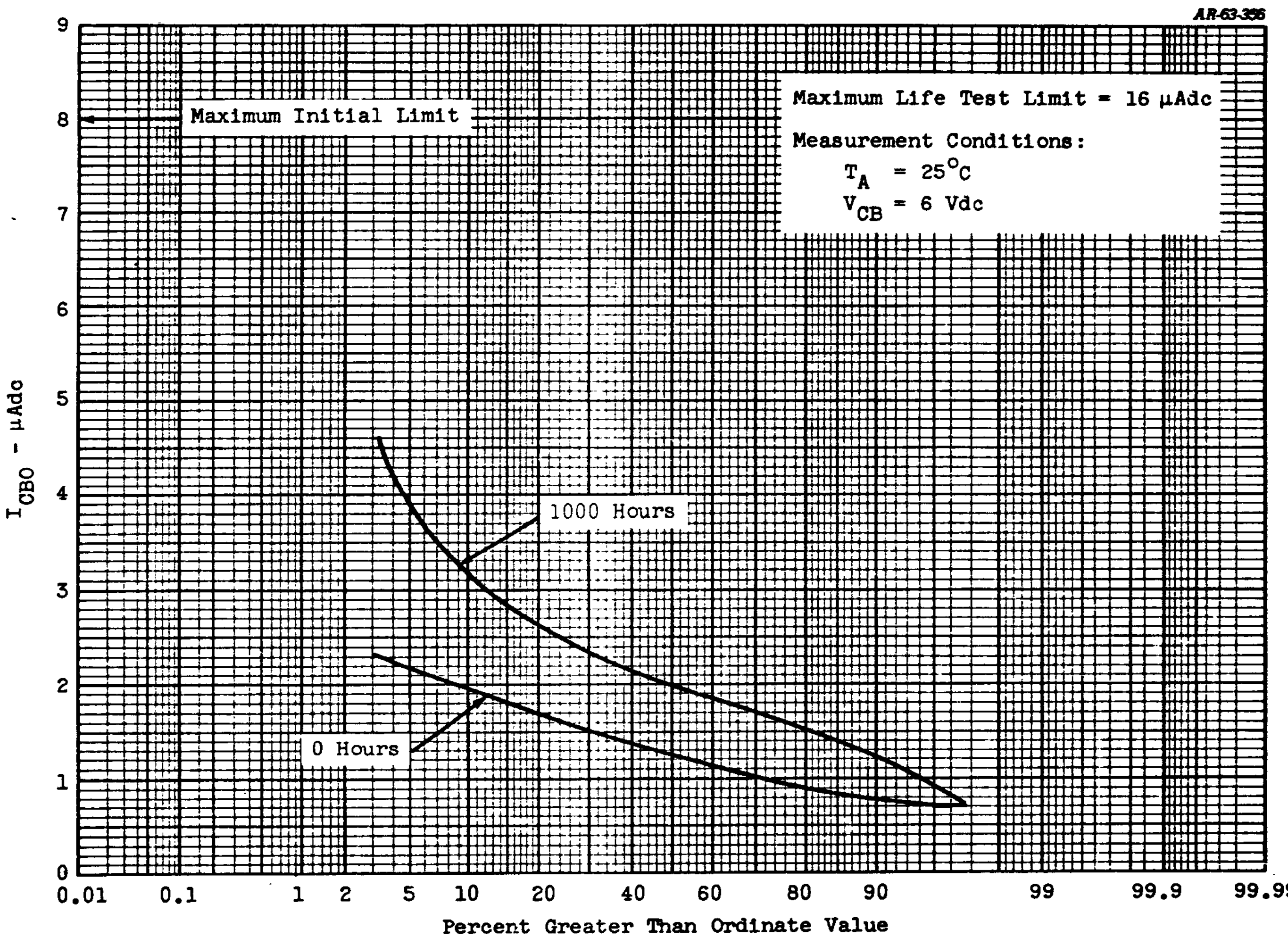

FIGURE 8

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 100mW OPERATING LIFE TEST (n = 30)

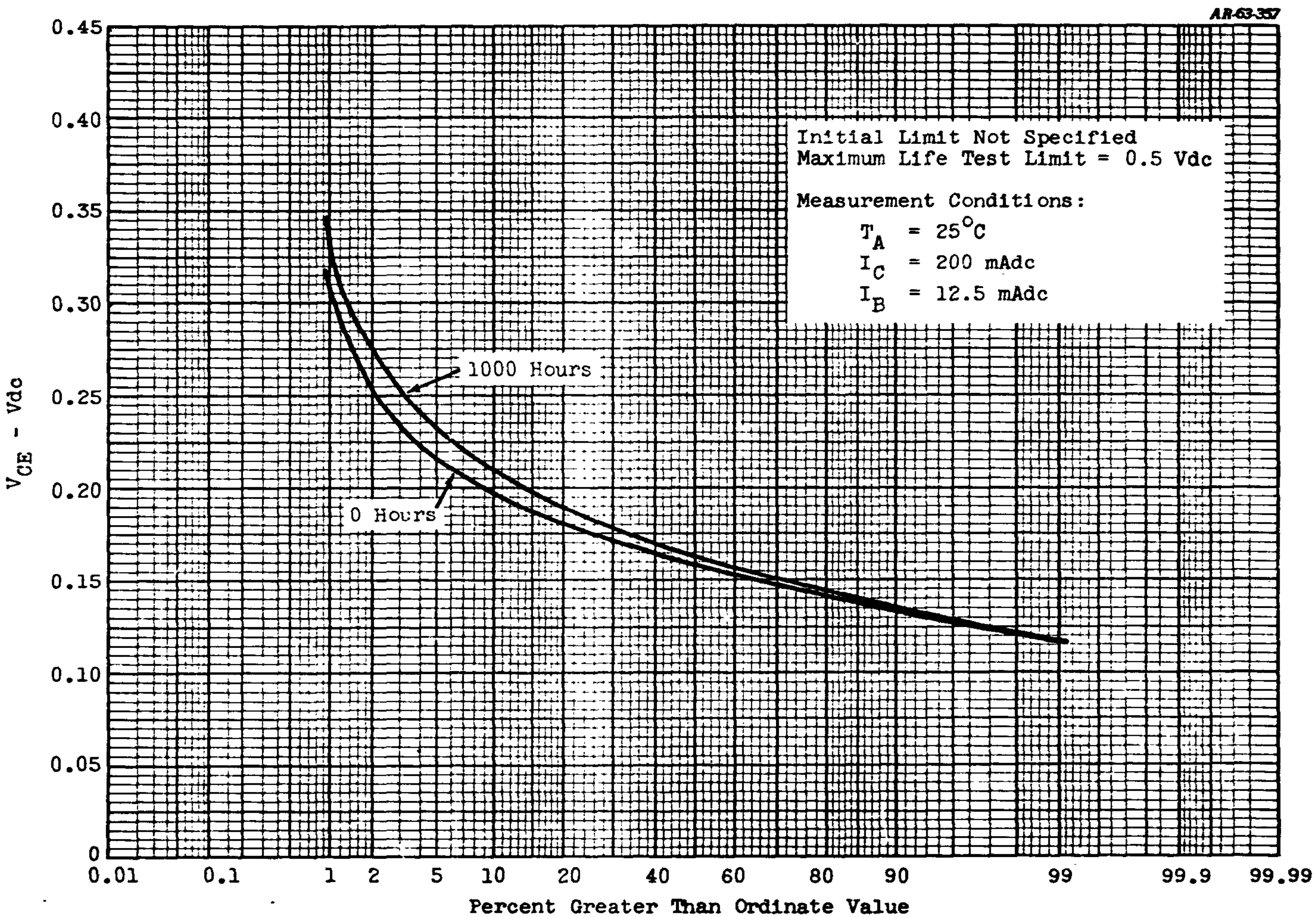

FIGURE 9

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF V_{CE} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 110)

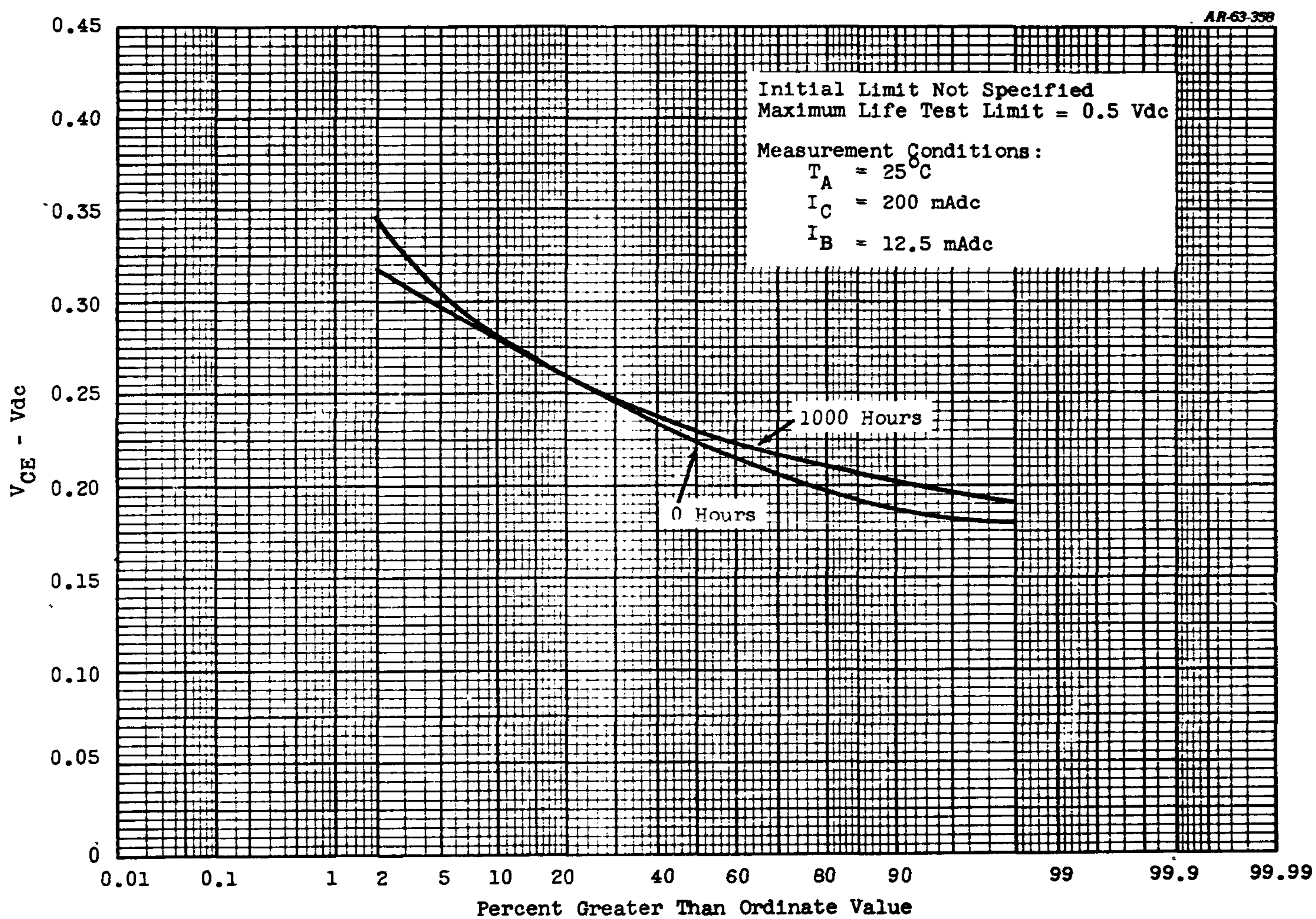

FIGURE 10

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF V_{CE} RESULTING FROM 1000-HOUR, 200mW OPERATING LIFE TEST (n = 50)

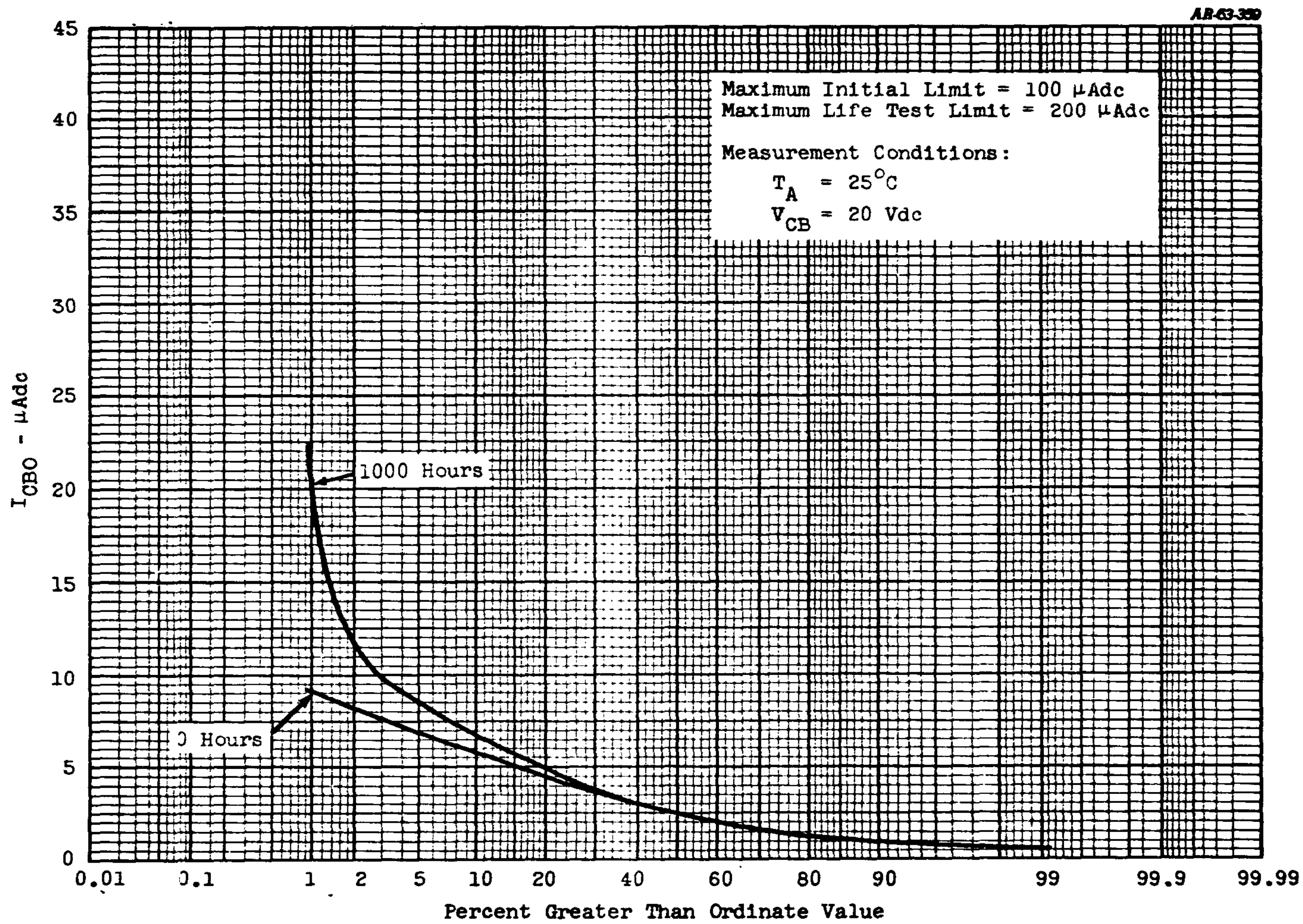

FIGURE 11

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 110)

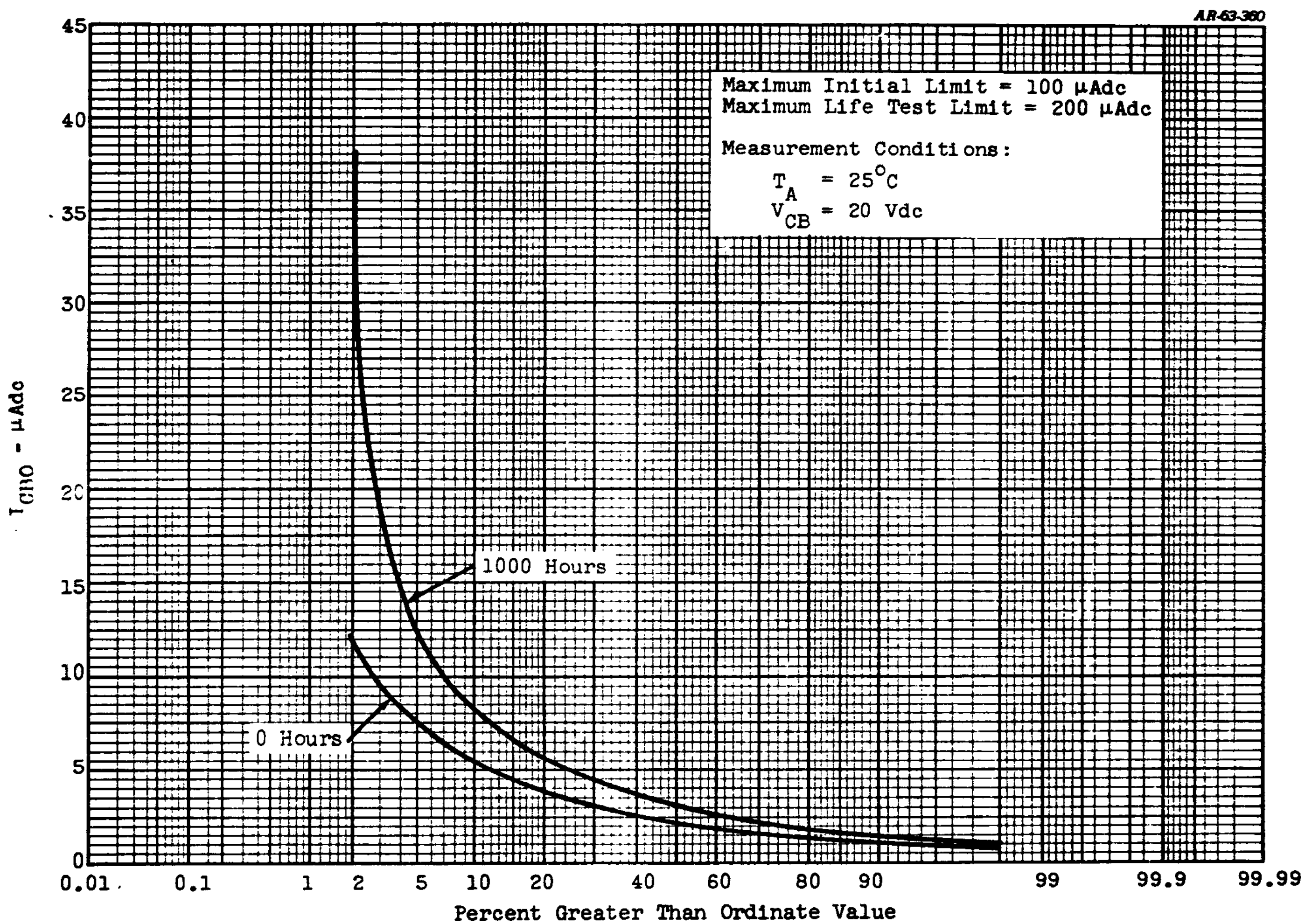

FIGURE 12

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 200mW OPERATING LIFE TEST (n = 50)

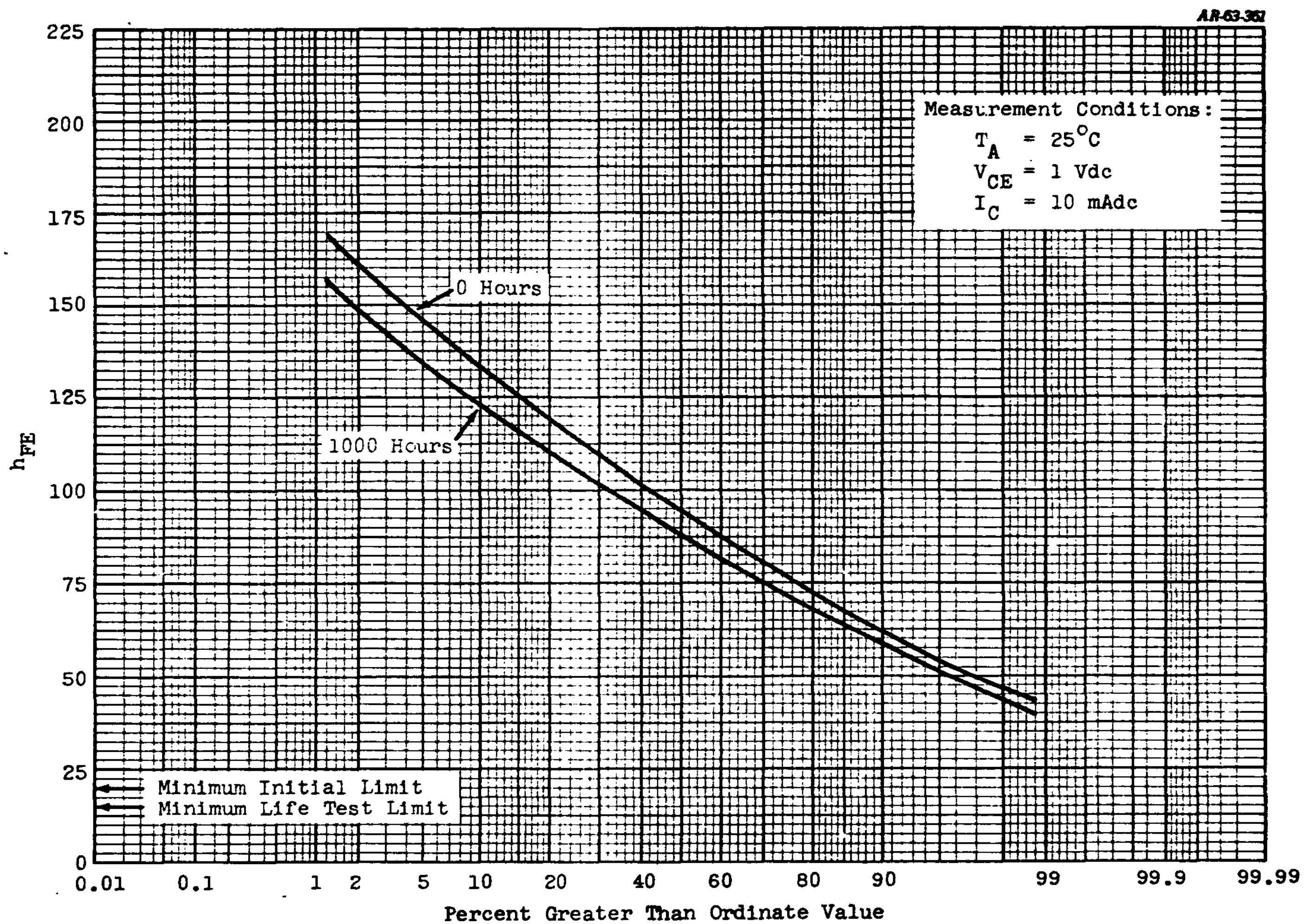

FIGURE 13

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 300°C STORAGE LIFE TEST (n = 80)

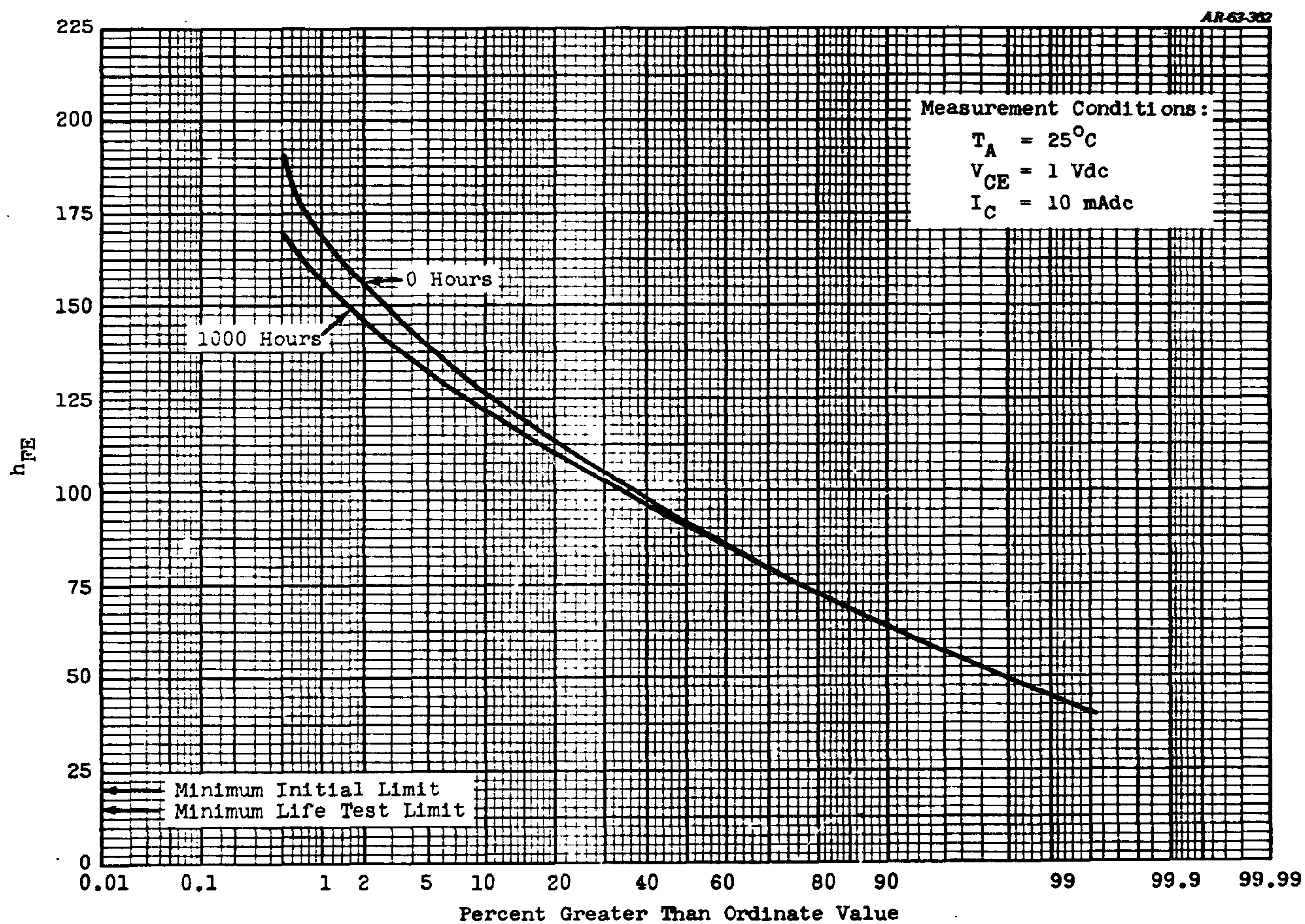

FIGURE 14

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 300mW OPERATING LIFE TEST (n = 200)

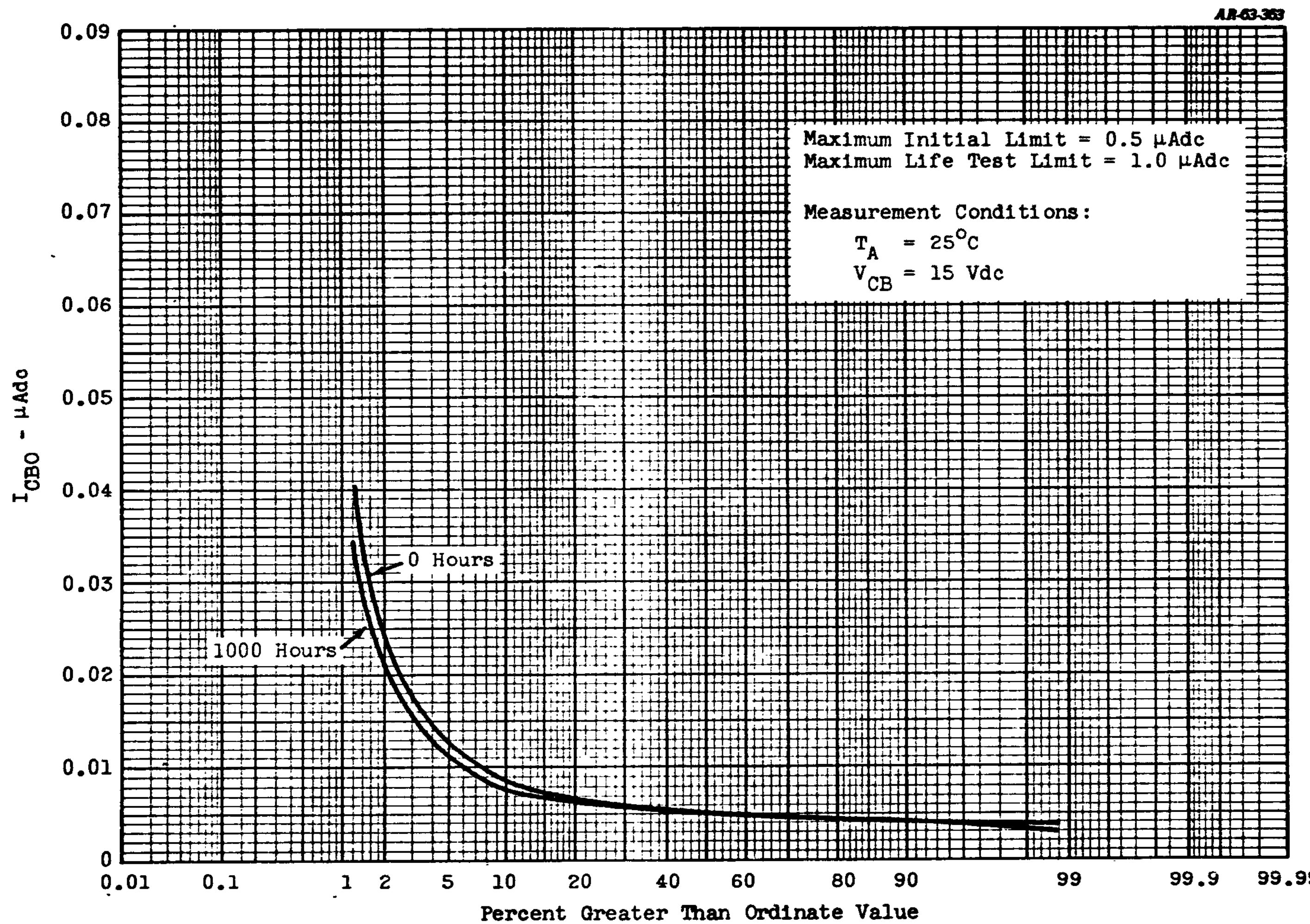

FIGURE 15

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 300°C STORAGE LIFE TEST (n = 80)

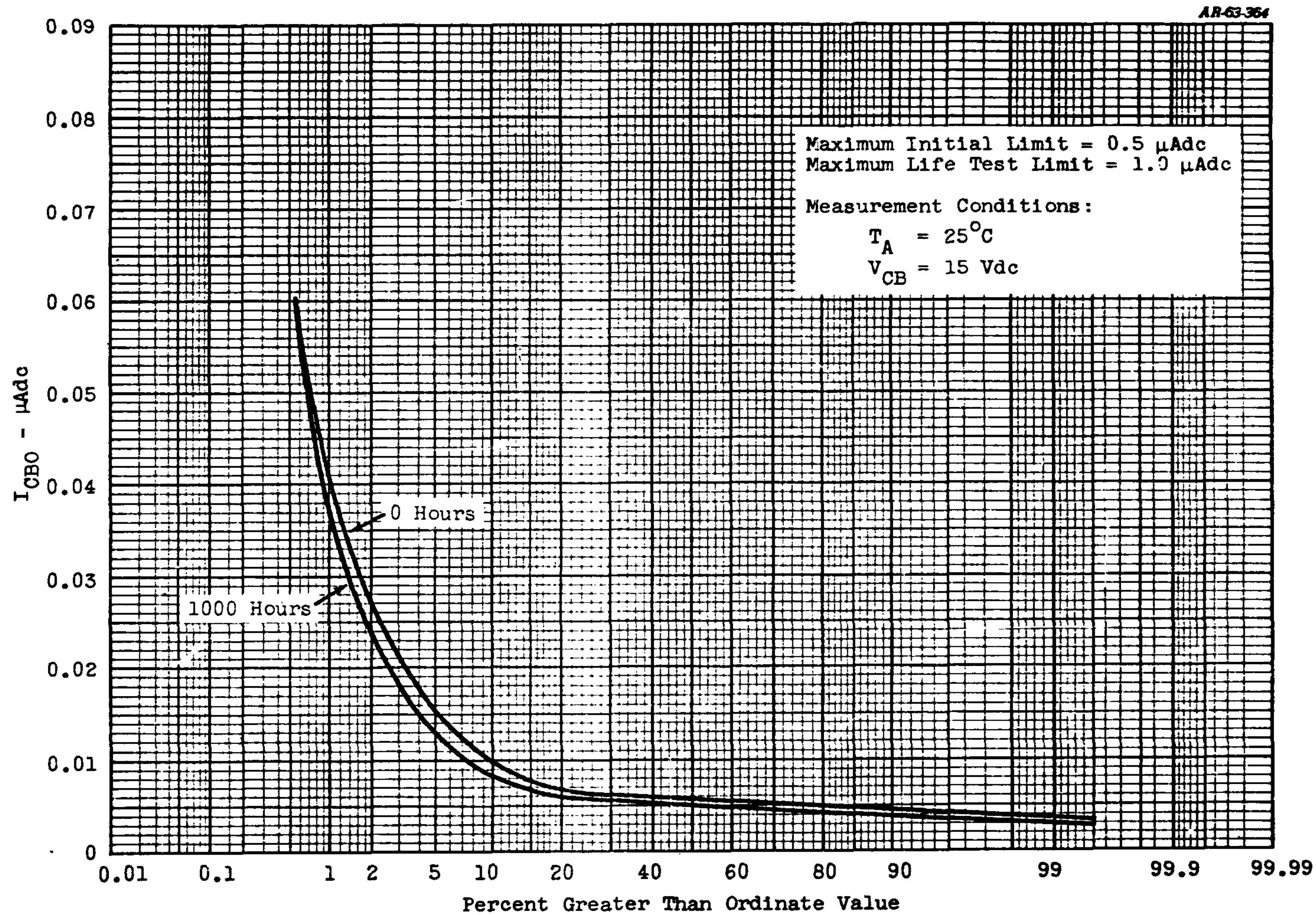

FIGURE 16

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 300mW OPERATING LIFE TEST (n = 200)

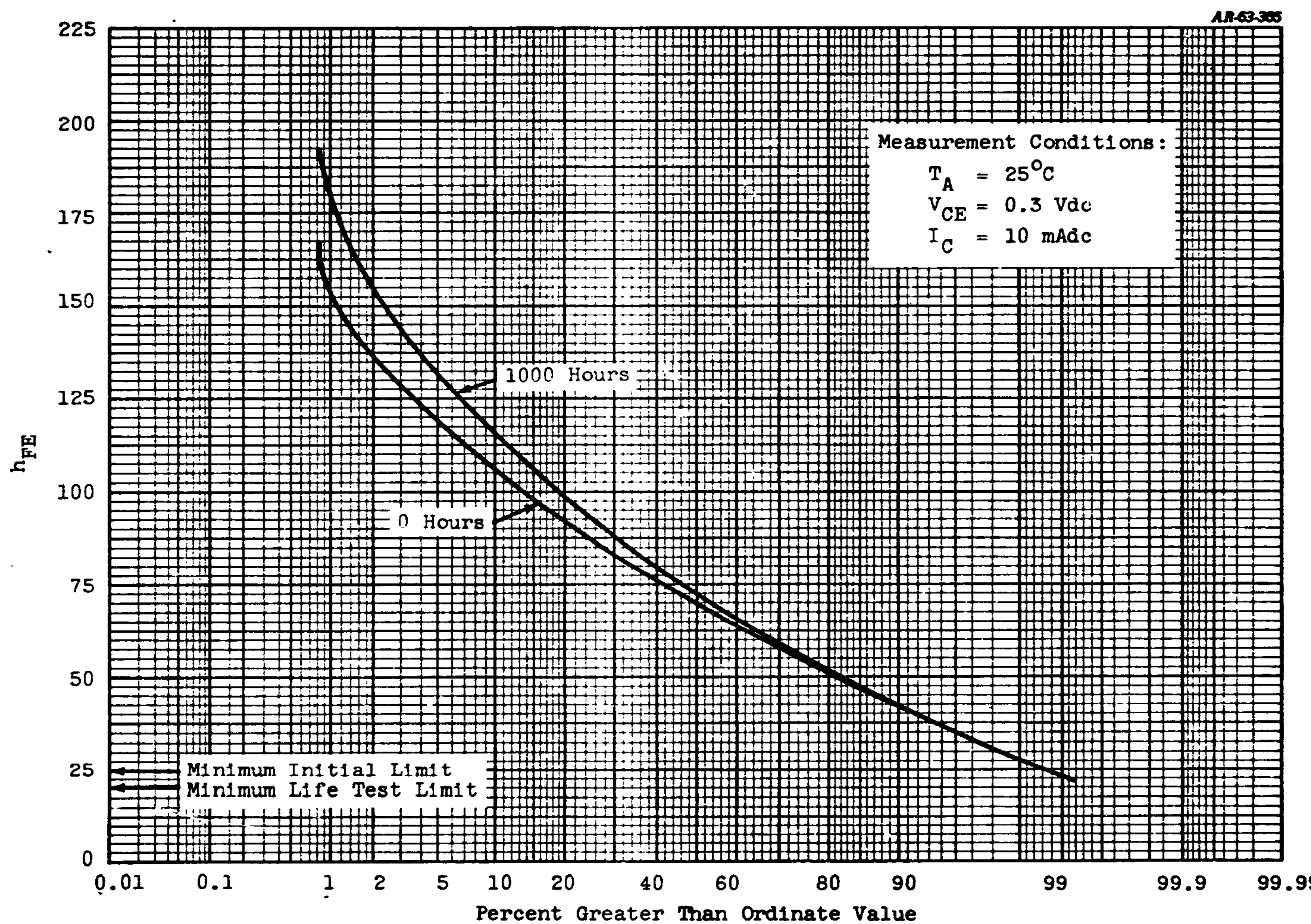

FIGURE 17

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 120)

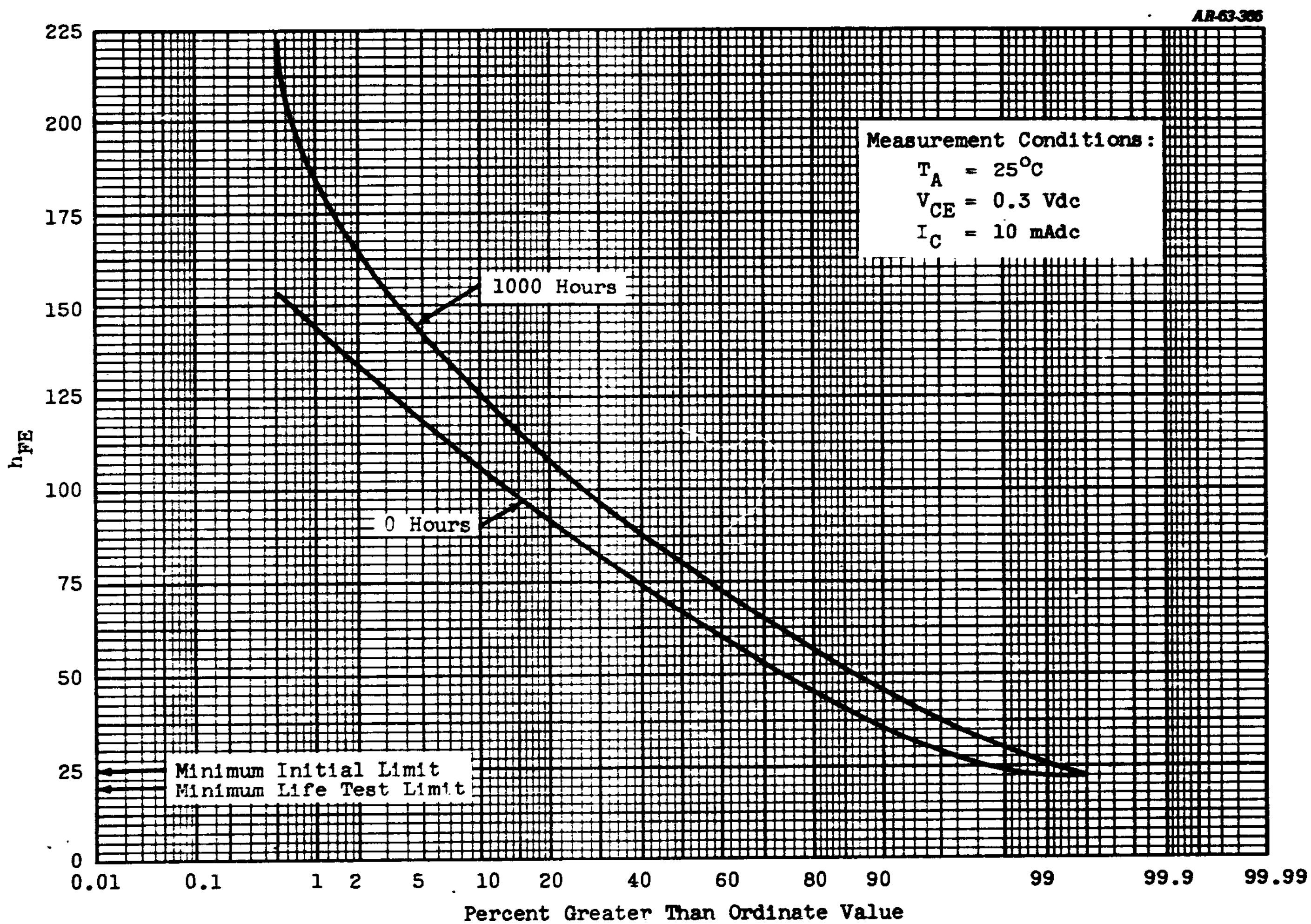

FIGURE 18

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF h_{FE} RESULTING FROM 1000-HOUR, 150mW OPERATING LIFE TEST (n = 200)

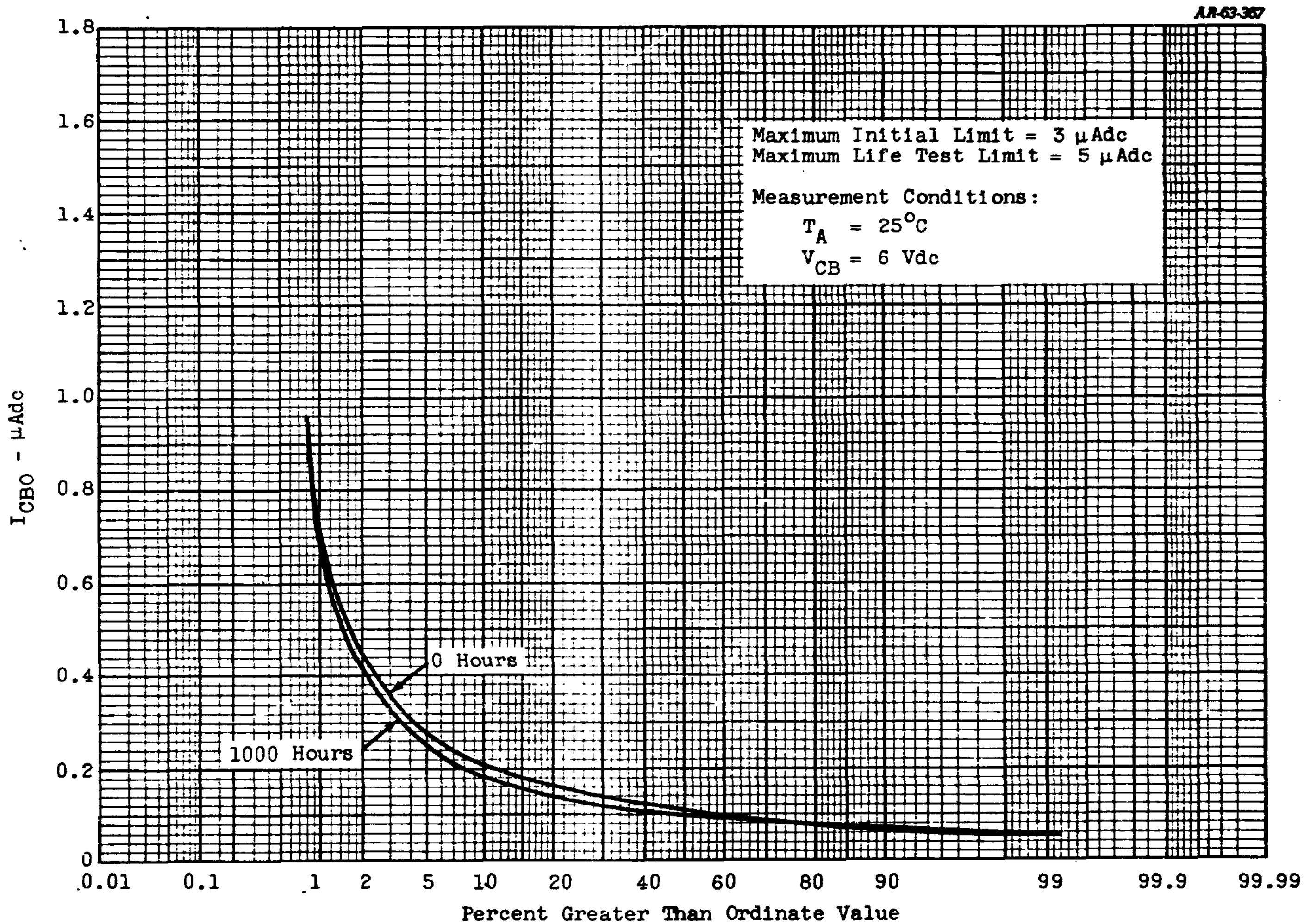

FIGURE 19

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 100°C STORAGE LIFE TEST (n = 120)

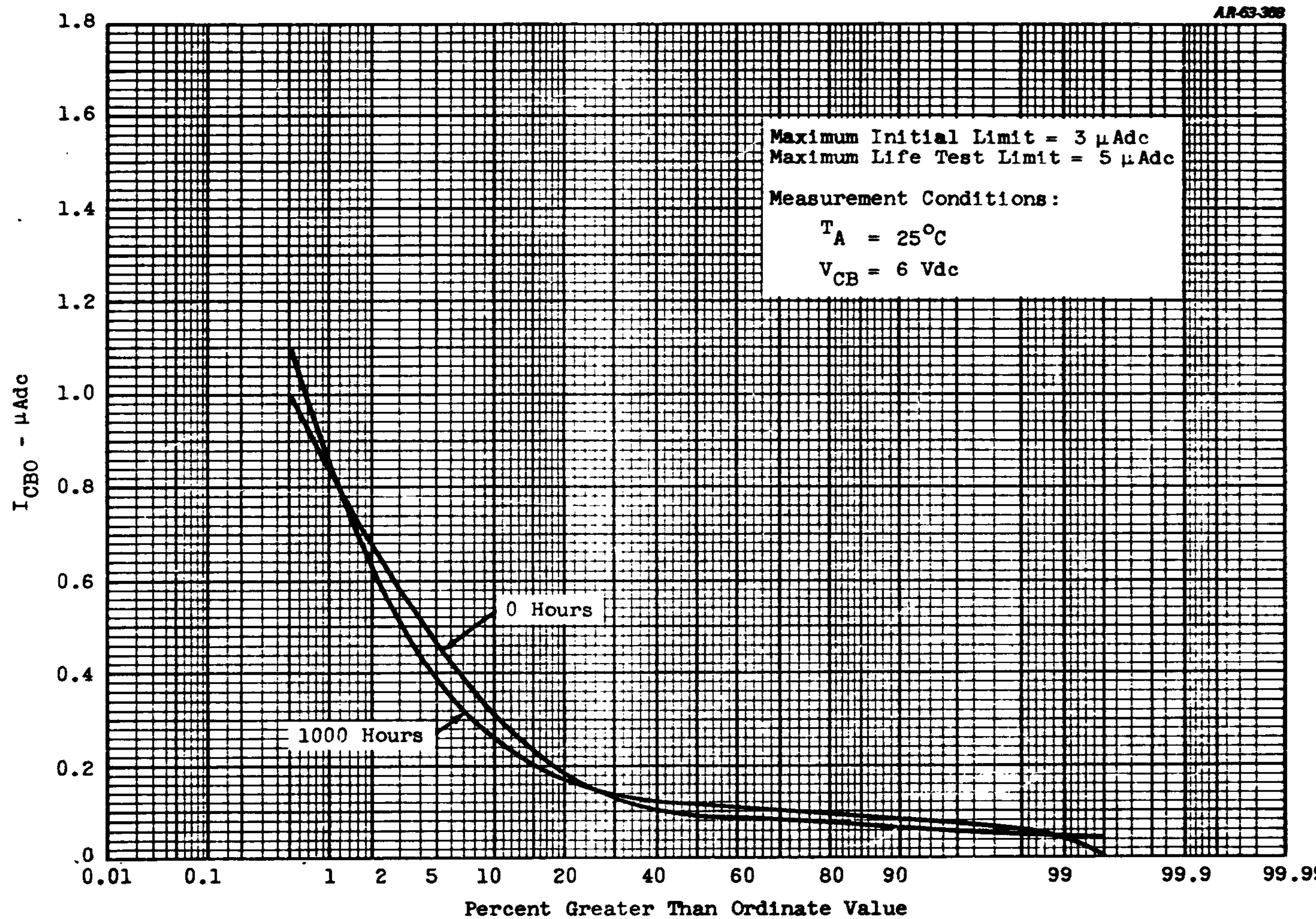

FIGURE 20

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF I_{CBO} RESULTING FROM 1000-HOUR, 150mW OPERATING LIFE TEST (n = 200)

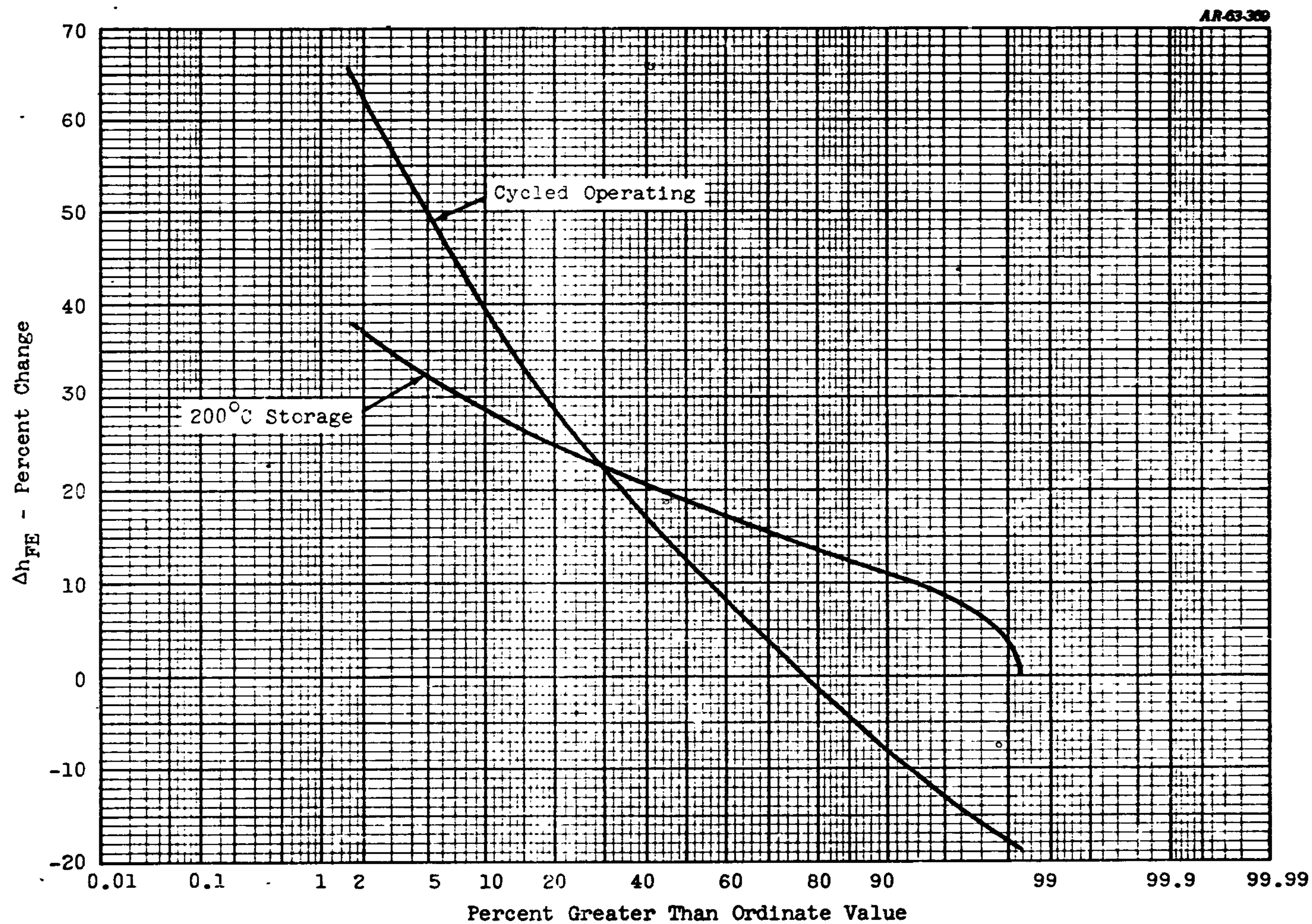

FIGURE 21

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF Δh_{FE} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

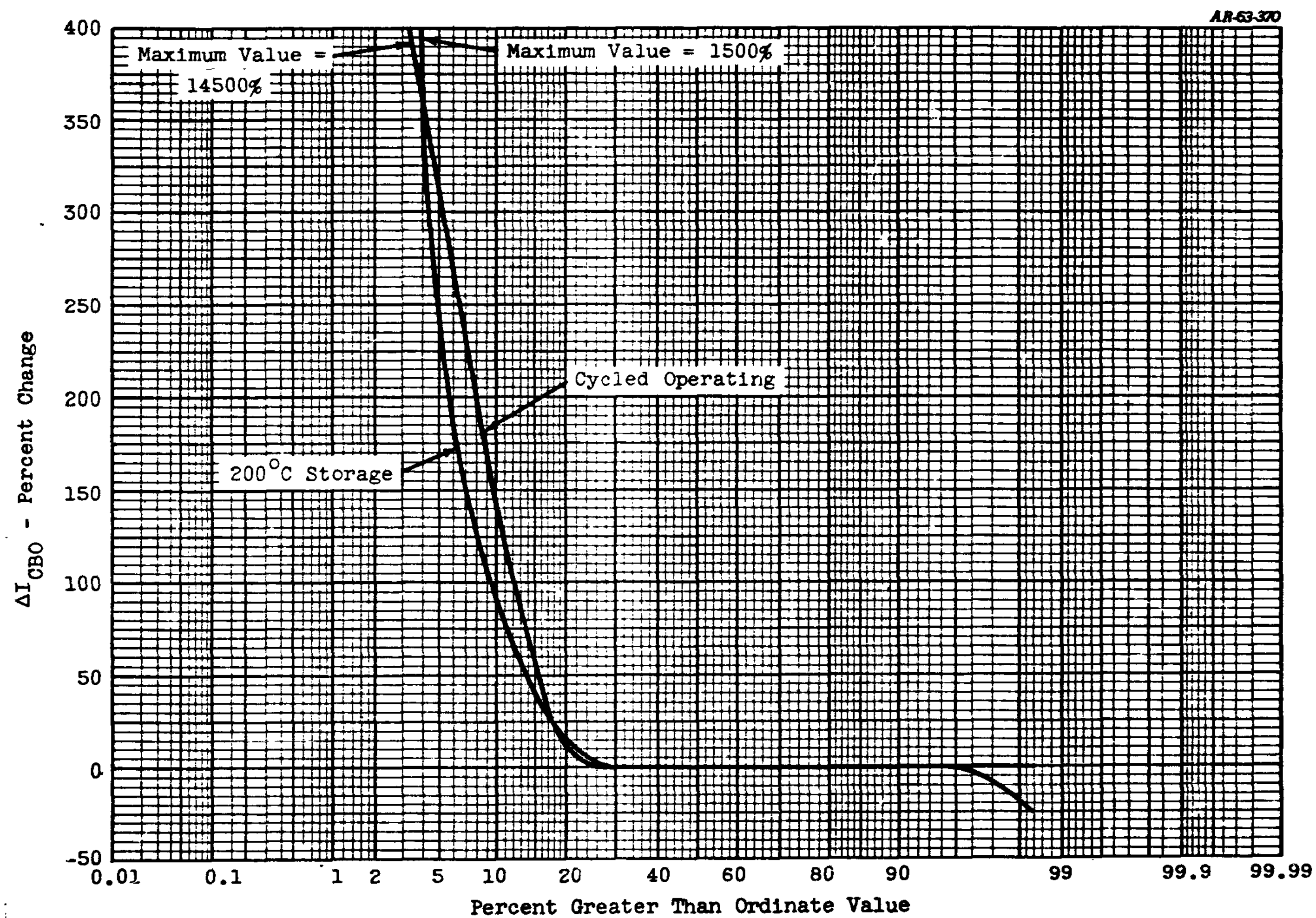

FIGURE 22

TRANSISTOR TYPES 2N1485 AND 2N1486, SOURCE F (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔI_{CBO} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

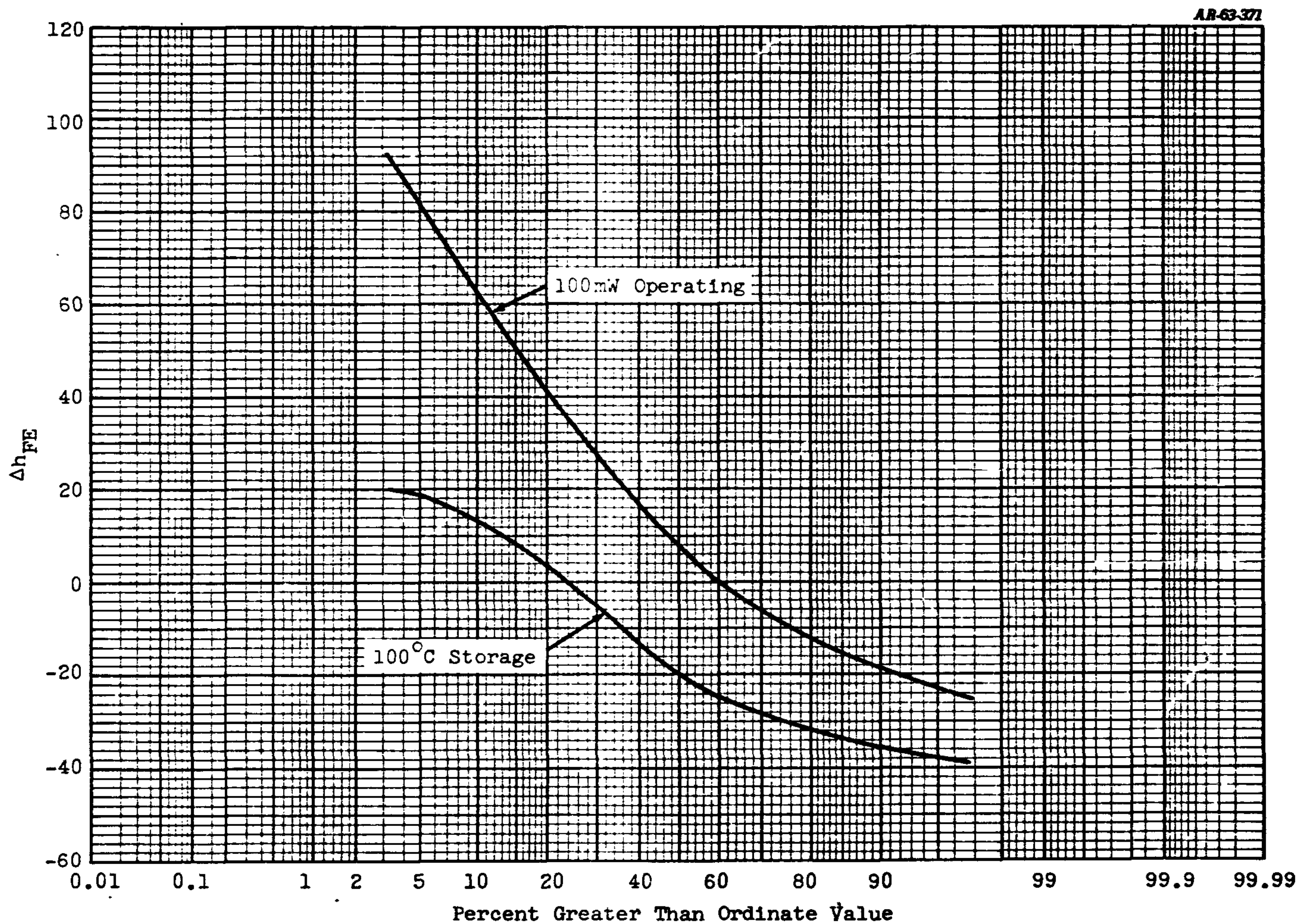

FIGURE 23

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF Δh_{FE} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

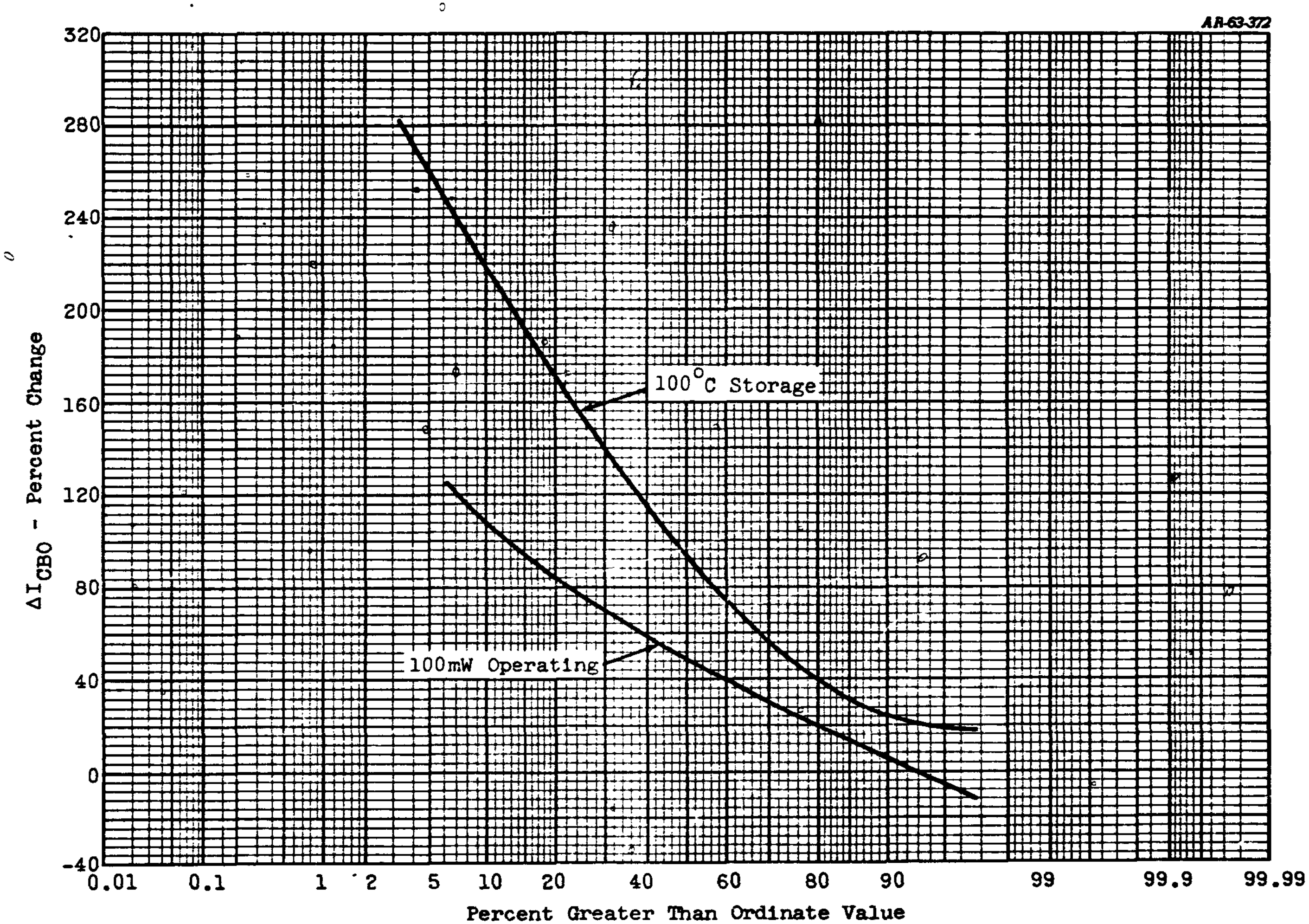

FIGURE 24

TRANSISTOR TYPE 2N2084, SOURCE H: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔI_{CBO} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

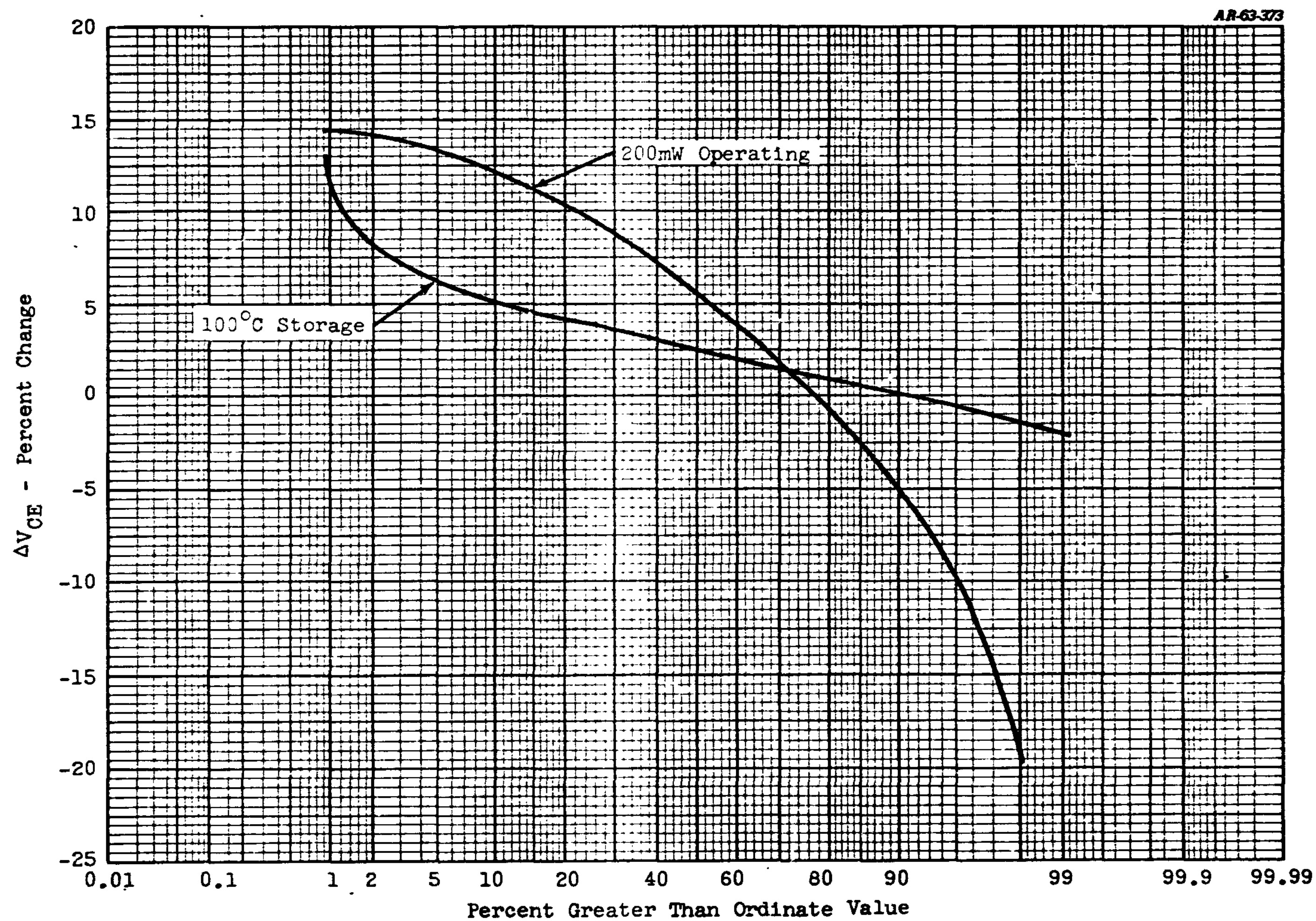

FIGURE 25

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔV_{CE} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

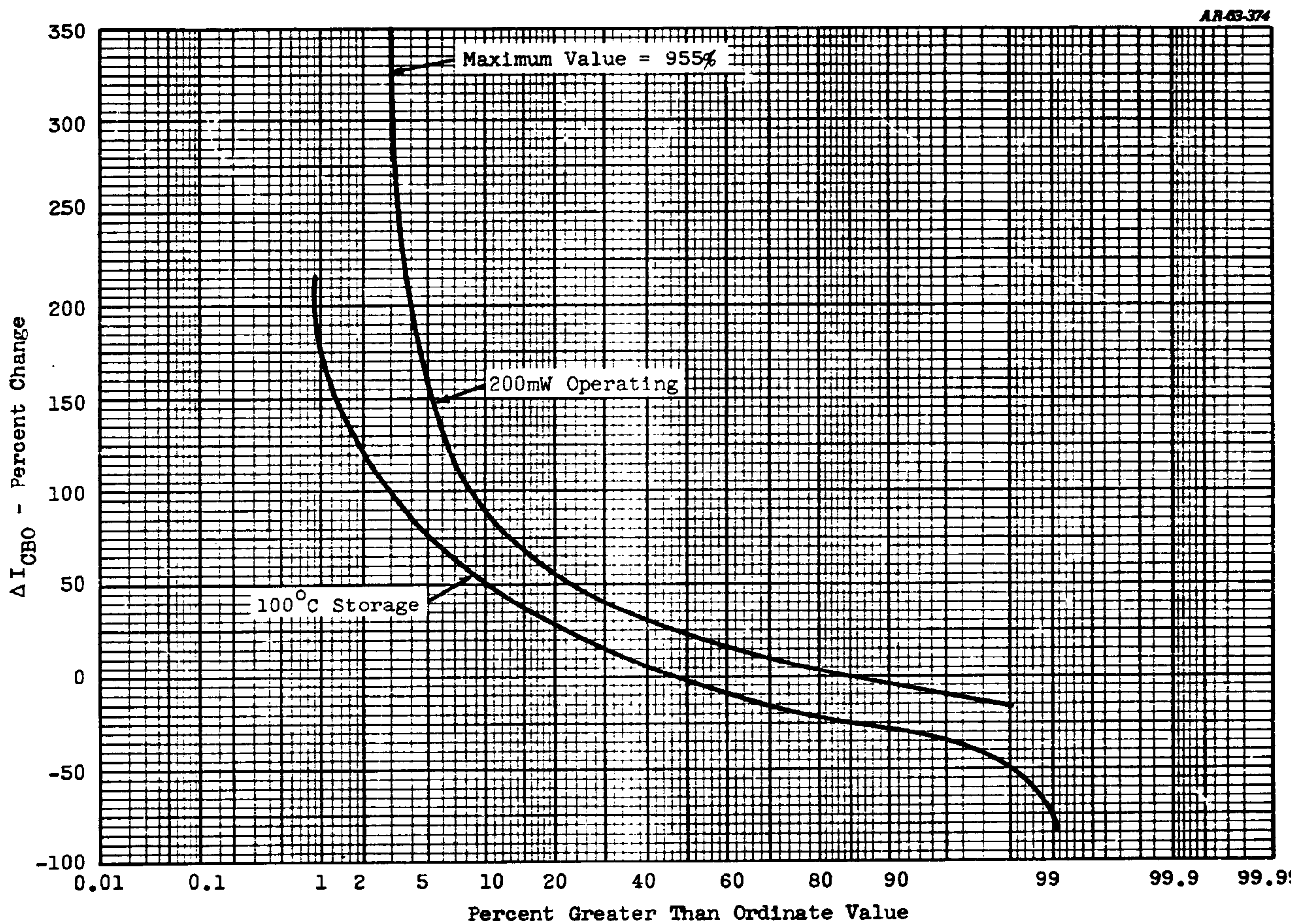

FIGURE 26

TRANSISTOR TYPE 2N1204, SOURCE I: CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔI_{CBO} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

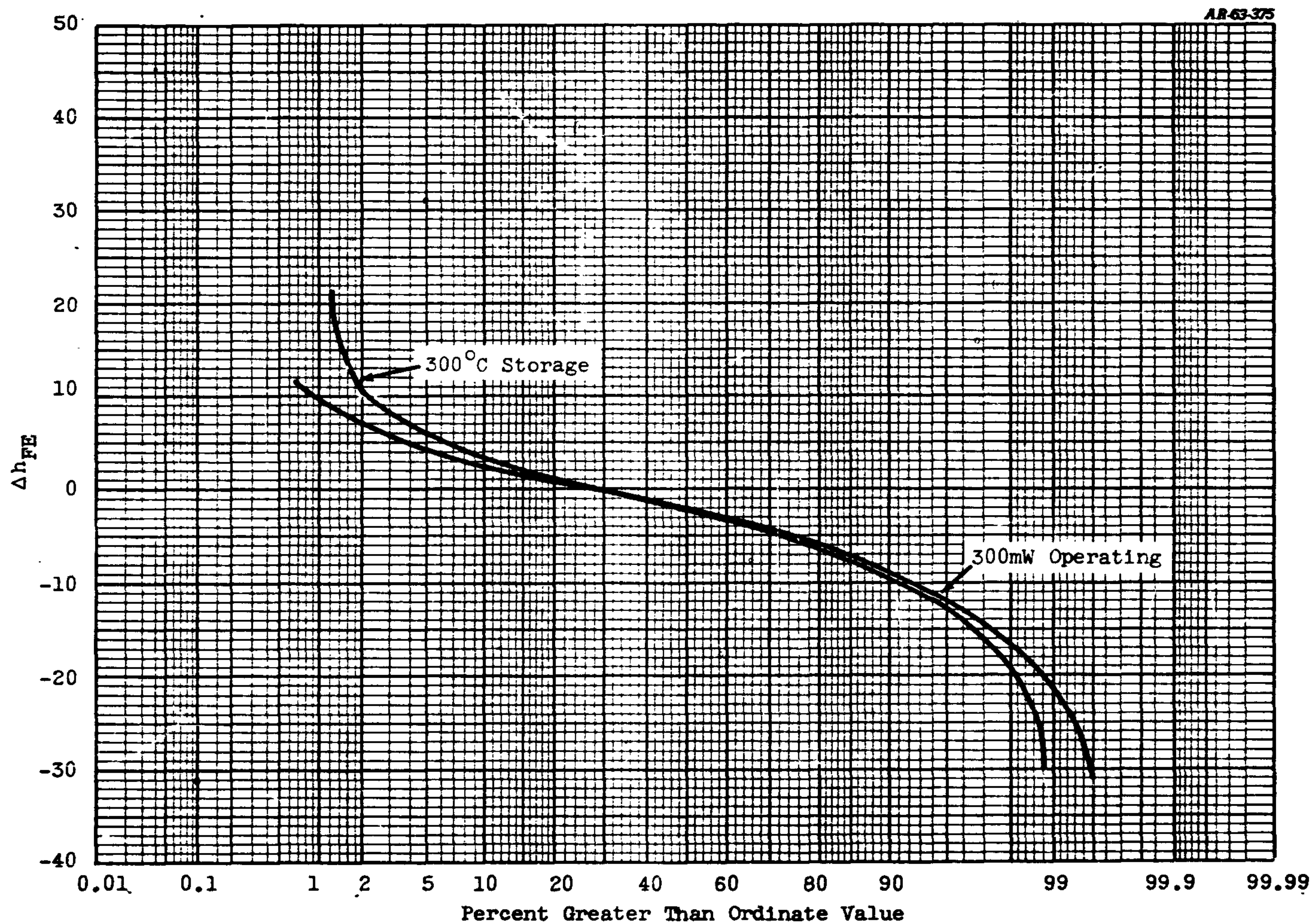

FIGURE 27

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF Δh_{FE} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

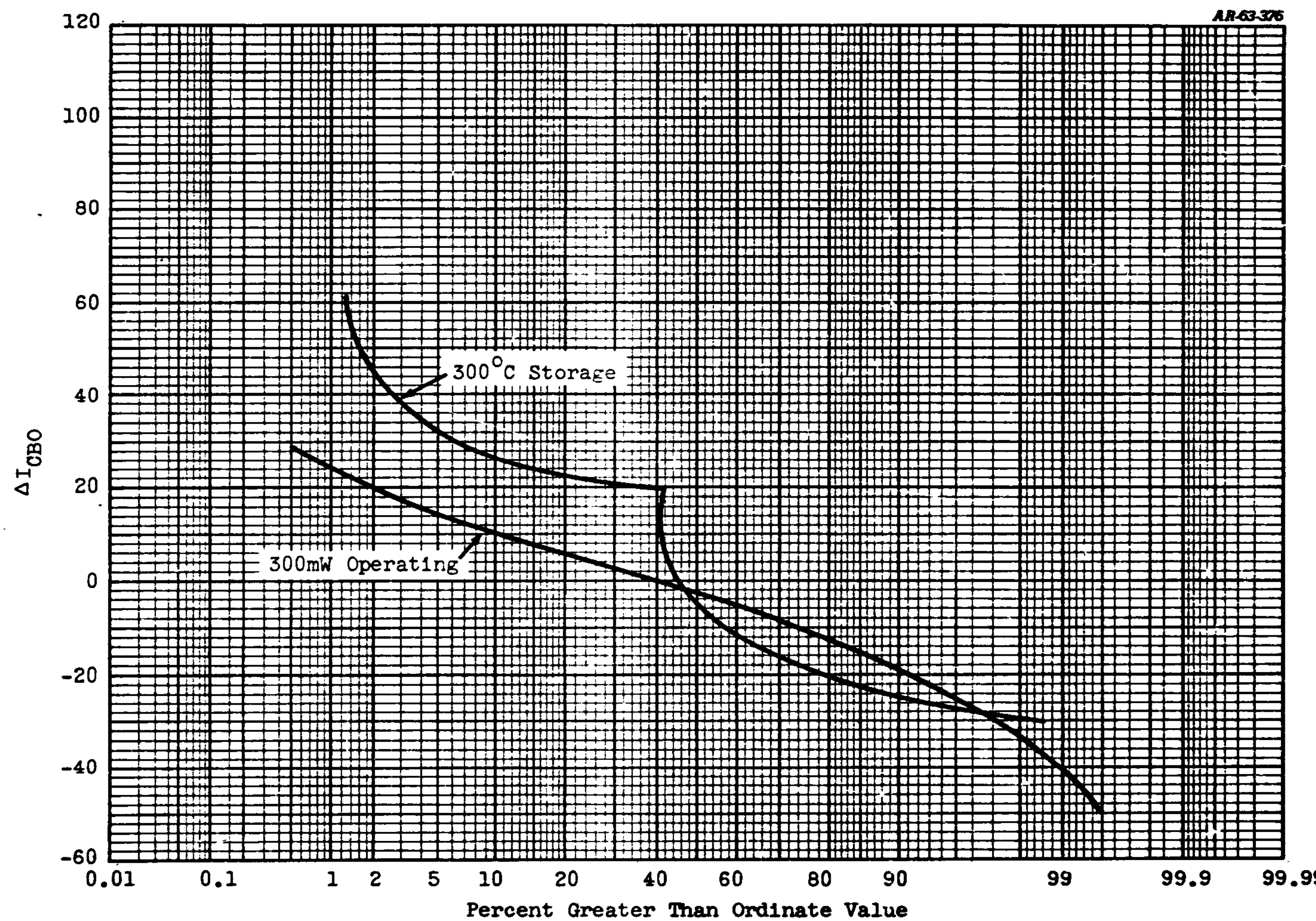

FIGURE 28

TRANSISTOR TYPES 2N914 AND 2N916, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔI_{CBO} AT 1000 HOURS FOR TWO 1000-HOUR LIFE TESTS

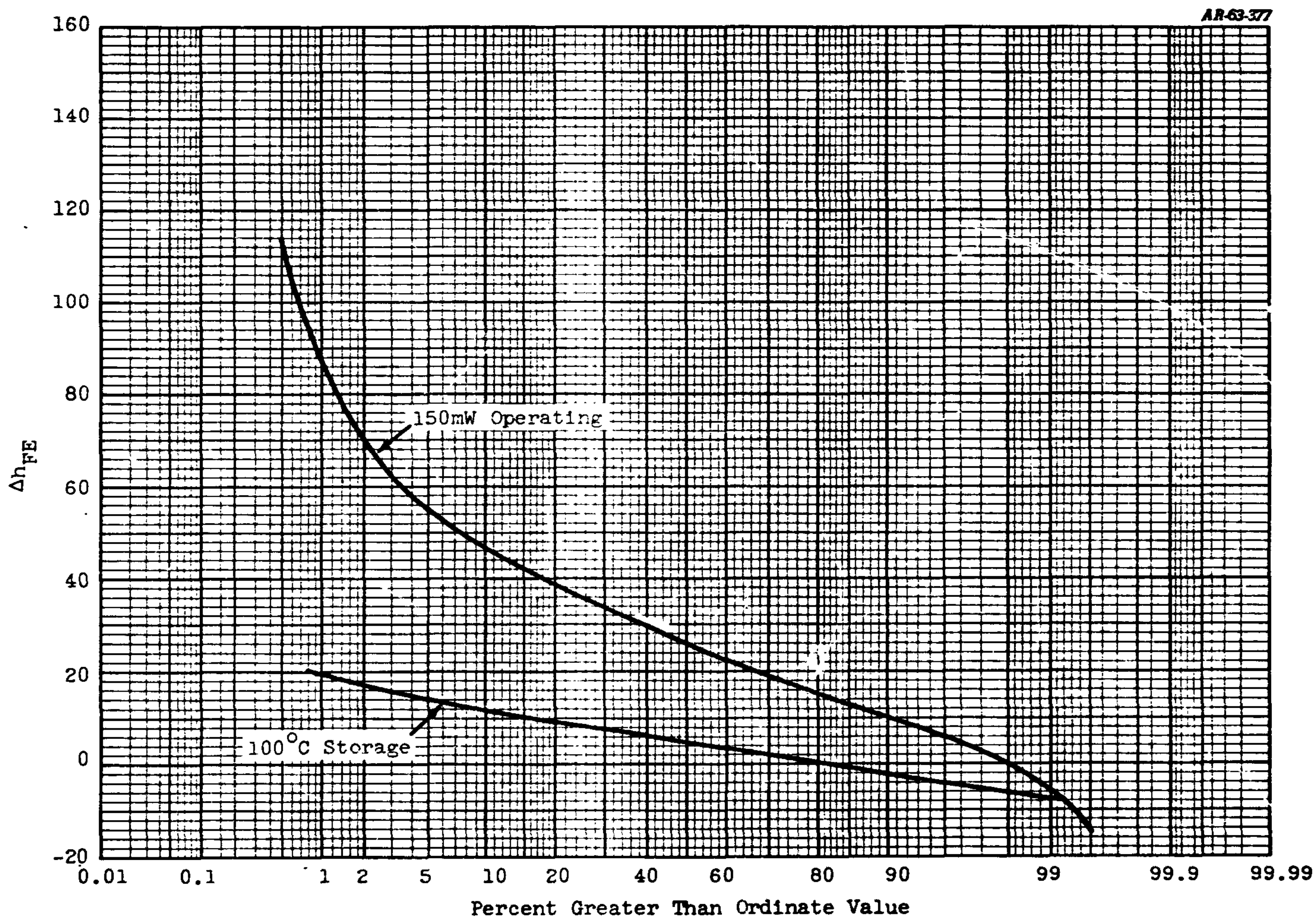

FIGURE 29

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF Δh_{FE} FOR TWO 1000-HOUR LIFE TESTS

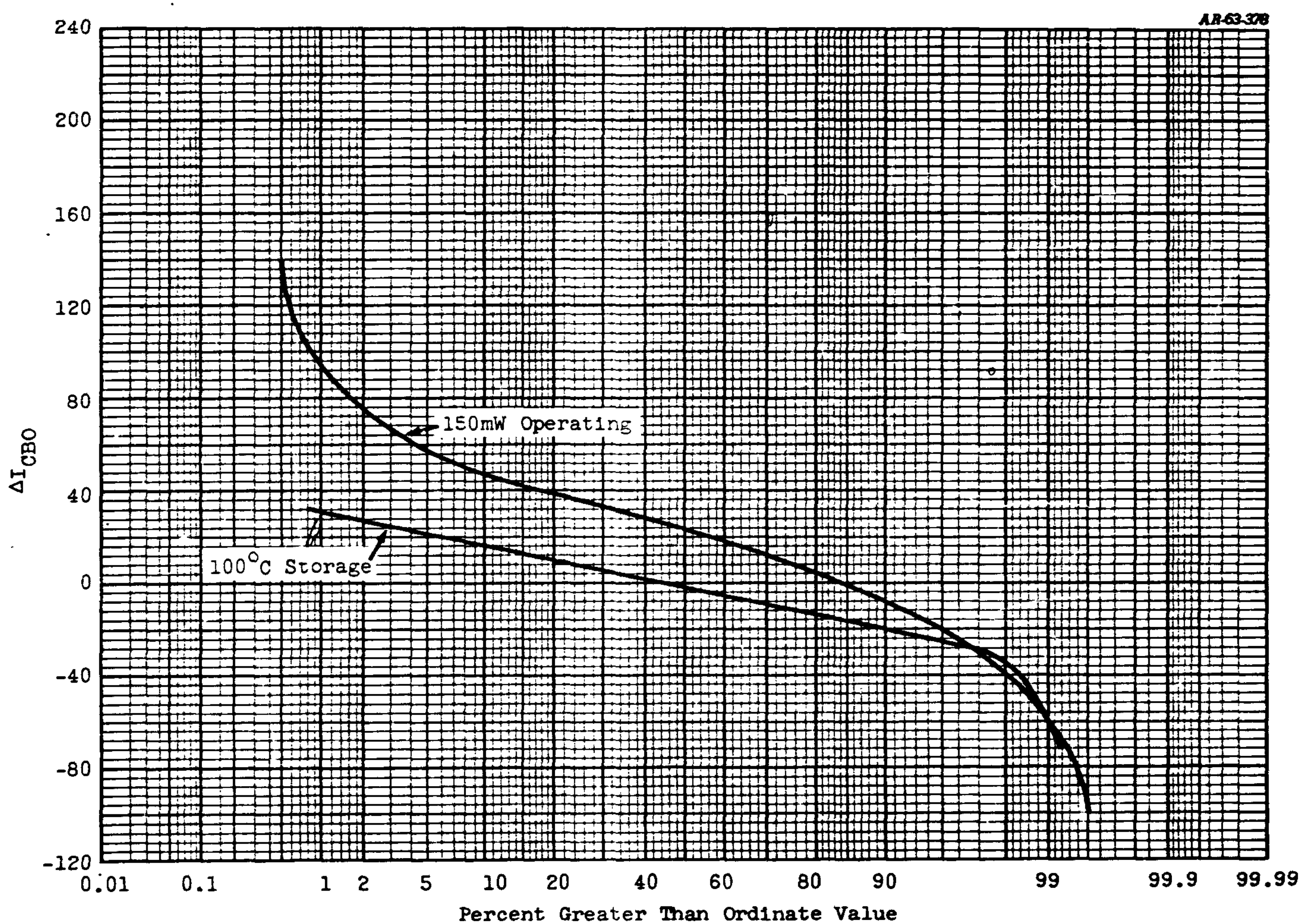

FIGURE 30

TRANSISTOR TYPES 2N962 AND 2N964, SOURCE J (COMBINED DATA): CUMULATIVE PERCENTAGE DISTRIBUTIONS OF ΔI_{CBO} FOR TWO 1000-HOUR LIFE TESTS

3.2.4 Hazard Rate Functions

Hazard rate, also known as the instantaneous failure rate, is defined by the formula:

$$Z(t) = \frac{\beta t^{\beta-1}}{\alpha}$$

where t is time adjusted to the particular scale in which the estimates of α are expressed (kilo- in this report).

Hazard rate functions are not shown for the 8 transistor types listed in Table 1; insufficient failures prevented the graphical estimation of the Weibull parameters, on which the curves are based (see the above equation).

3.3 Syncpsis

This report presents an analysis of life test data on 8 transistor types, consisting of:

(a) cumulative percentage distributions of electrical parameters at 0 and 1000 hours;

(b) cumulative percentage distributions of delta values at 1000 hours (as a basis for the study of transistor stability);

(c) failures per sample size for certain electrical parameters, based on initial and life test specification limits for specified time intervals of two 1000-hour life tests.

Graphical estimation of the Weibull shape parameter β and scale parameter α was extremely limited because the number of failures was negligible. For this reason, the computation of hazard rate functions was impractical.

3.4 Project Performance and Schedule

The tentative project schedule is shown in Table 7.

TABLE 7

PROJECT PERFORMANCE AND SCHEDULE

Task	Quarter*			
	1	2	3	4
1. Obtain data on reliability of transistorized equipments, including failure rates and failure modes of semiconductor devices.	(X)	(X)	(X)	X
2. Collect life test data.	(X)	(X)	(X)	
3. Analyze life test data (failure patterns, stability of units, failure acceleration techniques).		(X)	(X)	X
4. Program computer for estimation of confidence limits about Weibull shape parameter.	(X)			
5. Analyze computer output for Weibull estimation problem.		(X)	(X)	X
6. Prepare final report.				X

* X - proposed work; (X) - completed work.

4. PROJECTED WORK

The following studies are projected for the final quarter of the contract period:

(1) an analysis of life test data for the remaining transistor types;

(2) conclusion of a survey to obtain additional field reliability data, to determine the value of lot identification, and to ascertain special reliability tests now in use;

(3) conclusion of an investigation of the feasibility of employing Weibull sampling plans based on the average failure rate concept; and

(4) a comparison of Monte Carlo maximum likelihood estimates of Weibull parameters β and α with Monte Carlo least squares estimates of these parameters, for a few selected value combinations of β, α, sample size n, and truncation time t_r.